

Sinclair Stammers/SPL



SPACE FRONTIERS



MOON SHOT

'THAT'S ONE SMALL STEP FOR a man, one giant leap for Mankind,' Neil Armstrong announced to an audience of millions, glued to their television sets the world over, as he cautiously made the first footprint on the Moon.

History was made on 20 July 1969, four days after a mighty Saturn V rocket, over 110 metres tall, thundered skyward from its launch pad at Cape Canaveral, in Florida, USA.

Right on top of the rocket was the spacecraft, *Apollo 11*, which would be detached from the rocket to head for the Moon. Strapped into its cramped crew compartment, the command module, were astronauts Neil Armstrong, Edwin 'Buzz' Aldrin and Michael Collins – two of whom would be the first men ever to attempt to land upon another world.



Destination Moon

The rocket itself was made up of several 'stages'. These are separate sections designed to be jettisoned in space after each has fulfilled its

function in providing the necessary boost.

At 9.32 a.m. on Wednesday, 16 July 1969, 15 tonnes of fuel and liquid oxygen were burned each second as the rocket lifted off. Two and a half minutes later and 61 km up, the first stage separated and fell back to Earth. This had carried the vast quantity of fuel for the massive initial thrust.

At a speed of 9,978 km/h, the second stage fired, carrying the rest of the rocket a further 124 km higher, reaching a speed of 24,940 km/h within six and a half minutes.

Stage two now fell away, and the stage three rockets fired, carrying the spacecraft into orbit around the Earth. Later, the rockets fired again, this time setting *Apollo* on course to the Moon.

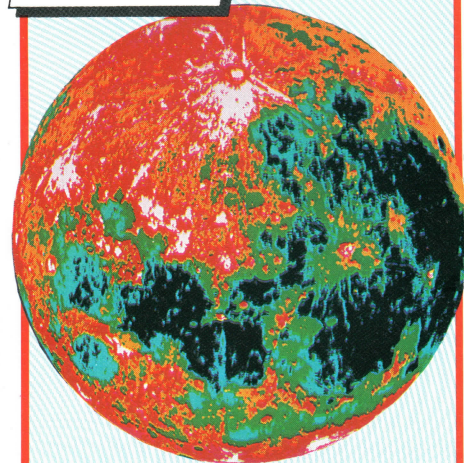
Astronaut Schmitt examines a giant boulder on the last Moon mission. It was probably one of many thrown up by the impact of a meteorite millions of years ago. Harrison Schmitt was the first real scientist to land on the Moon.

GETTING THERE

FIRST ON THE MOON

SPLASHDOWN

PROFILE THE MOON



Dr Fred Espenak/SPL

The Moon shows a vivid face in a false-coloured telescope photograph. Earth's only natural satellite, the Moon is lifeless, airless and rocky.

Diameter 3,476 km

Distance from Earth

furthest 406,600 km
nearest 356,300 km
average 384,000 km

Temperature

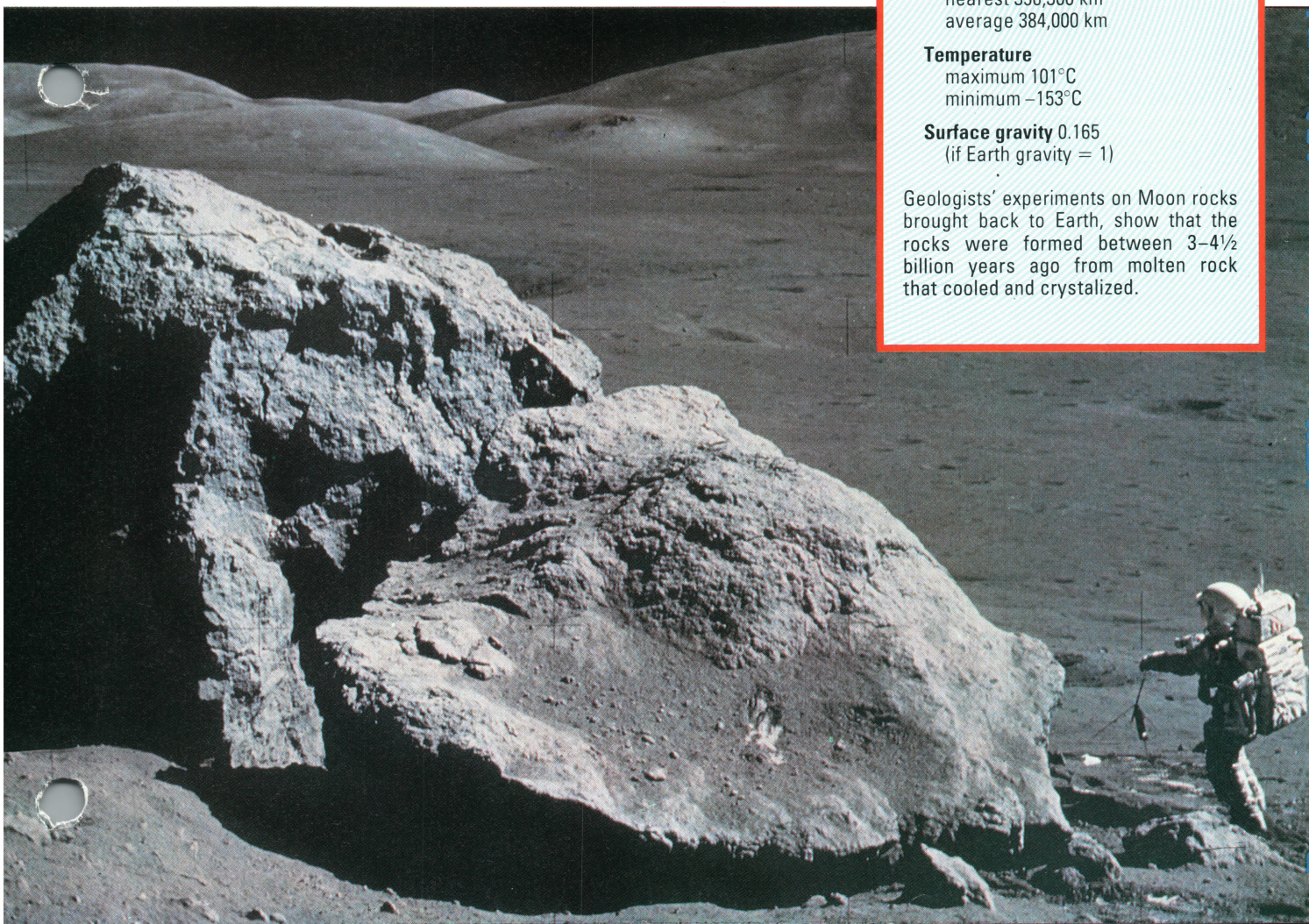
maximum 101°C
minimum -153°C

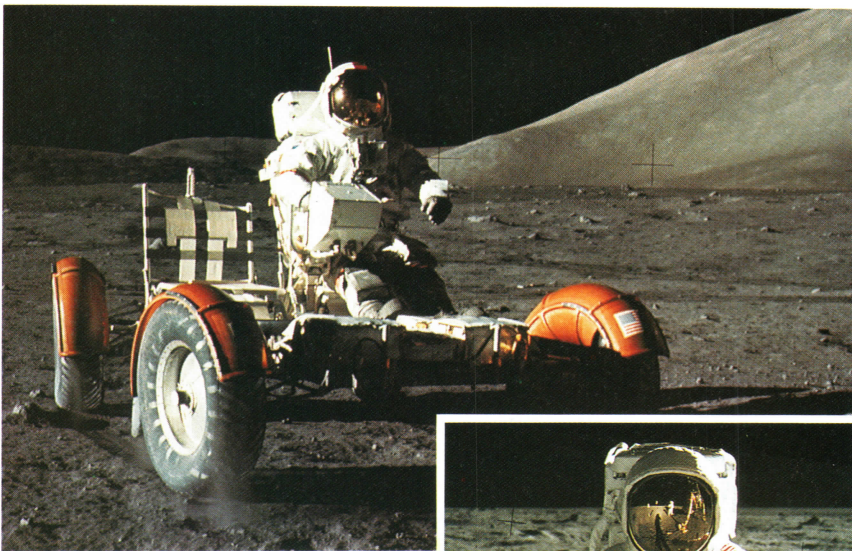
Surface gravity 0.165

(if Earth gravity = 1)

Geologists' experiments on Moon rocks brought back to Earth, show that the rocks were formed between 3-4½ billion years ago from molten rock that cooled and crystallized.

NASA



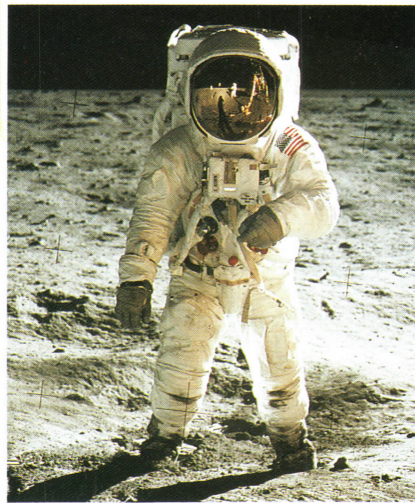


A Lunar Rover was used by later Apollo missions to taxi the astronauts on the Moon. It could also receive and send messages.

The Moonsuit is a mini home for the astronaut. It provides air, the right temperature and protects him from flying meteorites.

The Apollo spacecraft was also constructed in three parts. At the top was the command module that housed the crew. Behind this was the service module that contained the fuels and engine. And underneath was the lunar module, which would land the astronauts on the Moon and take them off again.

Once on course for the Moon, the service and command modules of



Apollo 11 came away from the lunar module – still housed within stage three of the rocket – and turned around 180°. The command module now docked with the lunar module.

Stage three of the rocket fell away. In orbit around the Moon, two of the astronauts, Armstrong and Aldrin, crawled into the lunar module via a tunnel.



Nicknamed 'Eagle', the lunar module now separated from its docking with the command and service modules and began its descent to the Moon.

The two astronauts spent 22 hours on the Moon. They collected over 20 kg of Moon rock and soil which, at first, were handled with extreme care in a specially sealed laboratory.

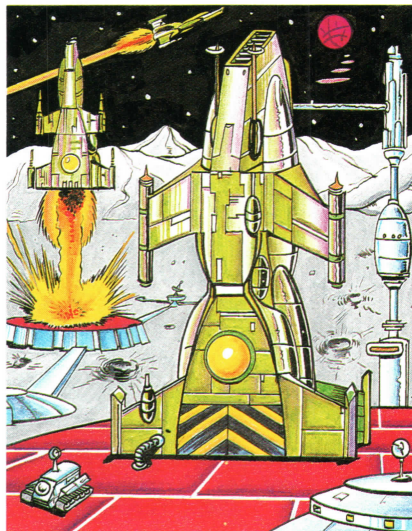
To return from the Moon, the astronauts took off from the top half of the lunar module, the lower half acting as a launch pad. After re-docking with the command module, they crawled back, leaving the lunar module in space. Just before re-entry, the faithful service module was finally ditched. The command module made its solitary return home to splashdown and a jubilant welcome.

INTO THE FUTURE

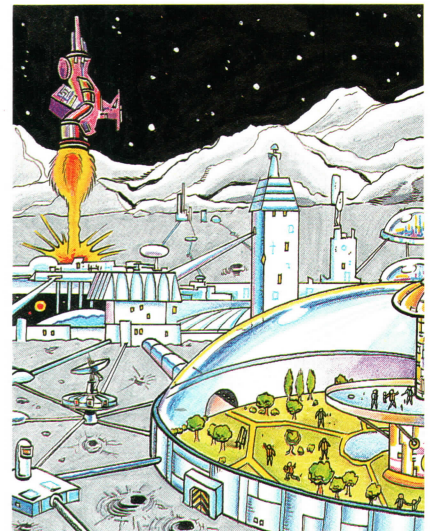
MOON COLONY



▲ Living on the Moon is a real possibility. At first, a few people could live there permanently, as water and oxygen can be made from the rocks and soil.



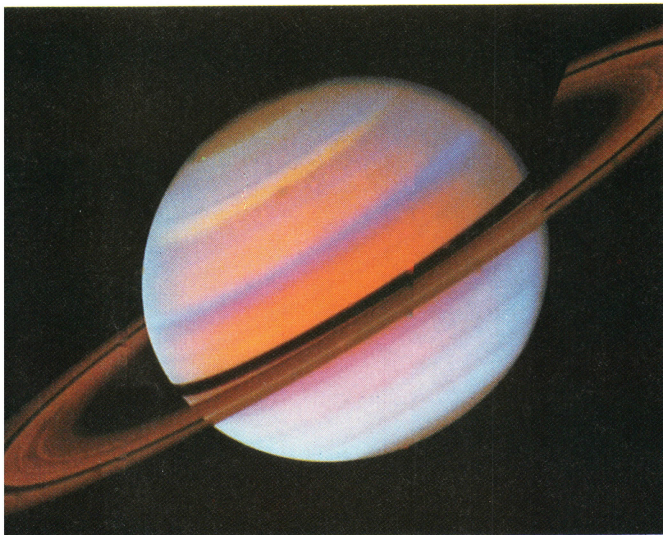
▲ Later, large spacecraft built from metals extracted from lunar rocks could be launched to provide two-way travel between Moon and Earth.



▲ In time, the Moon could accommodate more and more people. Children born there would consider the Moon their true home, returning to Earth only for visits.

THE OUTER PLANETS

Q GAS GIANTS Q RINGS Q MOONS



Saturn and its magnificent rings, photographed from the Voyager 1 spacecraft. Extra colour has been added to show up detail. Ammonia gas in the depths of the atmosphere appears as orange, while the bluish regions may be floating ammonia crystals. The rings of Saturn proved to be made up of thousands of 'ringlets' when seen close up from Voyager.

IMAGINE A SWIRLING STORM wider than the Earth that has been raging for over two centuries. Or a moon peppered with lakes of lava and huge, erupting volcanoes. Or a planet that seems to have been rammed by another world.



JPL, California

The moons of Jupiter show up starkly against their mother planet. (From the top) Io, Europa, Ganymede and Callisto are the four largest of Jupiter's 16 moons. All four satellites could fit snugly inside the Great Red Spot: end-to-end they measure 15,000 km, while the Spot is over 25,000 km long.

These are just some of the astounding discoveries scientists have made in the realm of the outer planets. Beyond the orbit of Mars, at many times the Earth's distance from the Sun, lie the planets Jupiter, Saturn, Uranus, Neptune and Pluto. All, except for tiny Pluto, are much bigger than our world.



The icy giants

As we move further from the Sun, we leave behind the warm, rocky worlds of the solar system, and enter a place where the Sun's heat and light is not so strong. There, the space is cold and the planets are frozen. This is the realm of the icy giants.

PROFILE

Planet Data

Skirting the outer limits of our solar system, the five outer planets offer a cold, inhospitable and alien environment where the days merge into years and the years into centuries.

	Jupiter	Saturn	Uranus	Neptune	Pluto
Distance from Sun (million km)	778	1,427	2,870	4,497	5,900
Diameter (km)	142,796	120,000	50,800	48,600	2,250
Length of day	9 h 50 m	10 h 13 m	17 h 14 m	18 h 24 m	6 h 23 m
Length of year (in Earth years)	11.9	29.5	84.0	164.8	247.7
Temperature (cloudtops)	-150°C	-180°C	-210°C	-220°C	-240°C
Number of moons	16	21	15	8	1

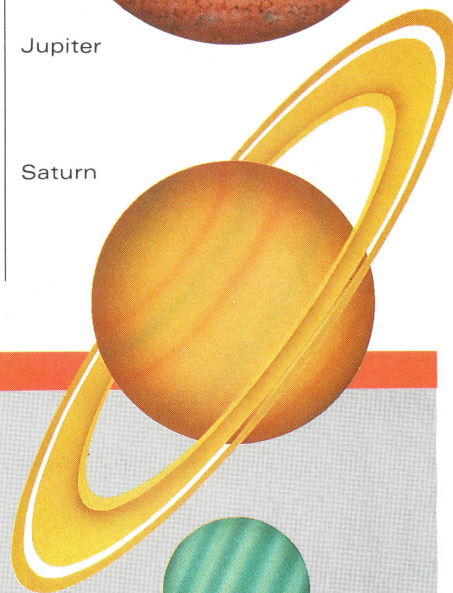
Jupiter, for instance, is so huge it could swallow up 1,300 Earths. Like its giant neighbours, Jupiter has no visible solid surface. All that can be seen from space is the top of its whirling, multi-coloured atmosphere of hydrogen, helium, methane and ammonia. Thousands of kilometres thick, this huge gassy blanket is thought to hide an even deeper, syrupy ocean of liquid hydrogen. Only at the planet's very centre is there perhaps a hard core of rock and metal, not much bigger than the Earth.

Best known of Jupiter's features is its Great Red Spot. An enormous oval whirlpool of gas with winds howling around its edge at 360 km/h, the Spot measures up to 25,000 km in length. No-one knows when it first formed. Jupiter and its family of 16 moons are like a miniature solar system. So, too, is Saturn, the next planet out, at almost twice Jupiter's distance from the Sun.

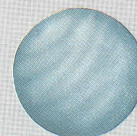


Jupiter

Saturn



Uranus



Neptune

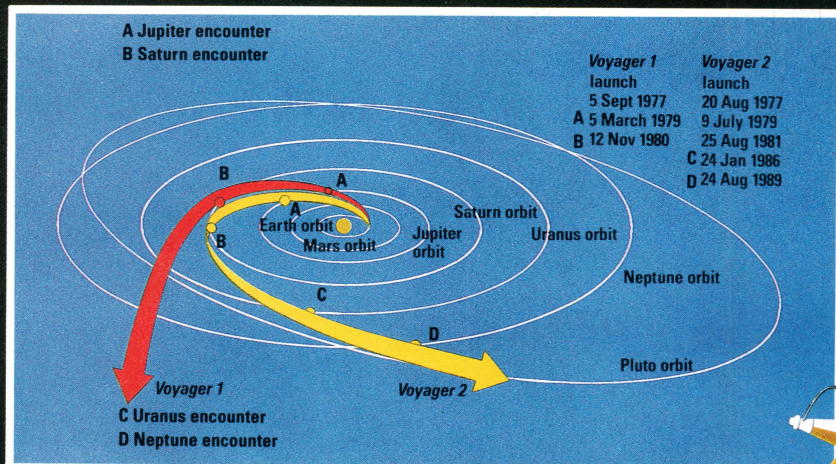


Pluto

Mark Franklin

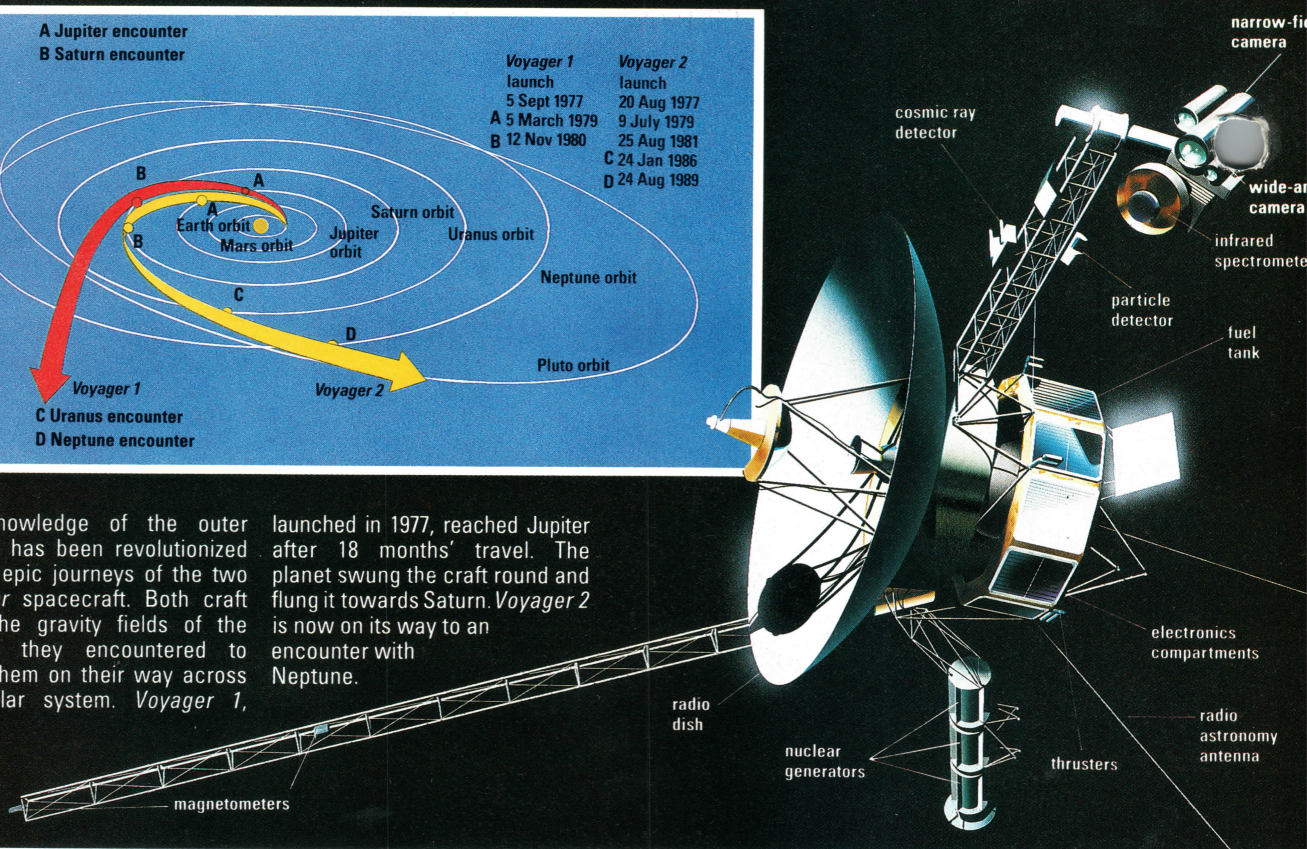


THE ORBITS OF VOYAGERS 1 AND 2



Our knowledge of the outer planets has been revolutionized by the epic journeys of the two *Voyager* spacecraft. Both craft used the gravity fields of the planets they encountered to boost them on their way across the solar system. *Voyager 1*,

launched in 1977, reached Jupiter after 18 months' travel. The planet swung the craft round and flung it towards Saturn. *Voyager 2* is now on its way to an encounter with Neptune.



At least 21 satellites move in orbit around Saturn. The biggest is Titan, whose surface is forever veiled by a thick red smog. But what makes Saturn spectacular is its fabulous collection of rings. Although from far away they seem solid, the rings actually consist of countless numbers of small chunks of rock and

ice, wheeling around Saturn like tiny moons.

Until recently, Saturn was thought to be the only ringed member of the Sun's kingdom. But scientists have recently learned that Jupiter, Uranus and Neptune are surrounded by rings.

Eleven narrow rings, blacker than charcoal, encircle the mysterious planet Uranus. So, too, do 15 known moons – among them little Miranda, with its amazing jumbled-up surface. Miranda may have been blasted apart on at least five separate occasions, when other objects crashed into it. But each time the fragments of the little moon stubbornly reassembled themselves.

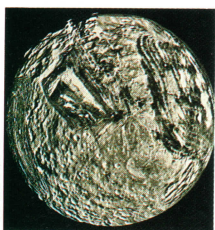
When worlds collide

Not only Miranda may have suffered collisions in the remote past. For many years, astronomers have wondered why Uranus, unlike every other planet, spins around on its side. The most popular explanation is that, billions of years ago, another object – maybe an Earth-sized planet – blundered into it at high speed, completely bowling it over.

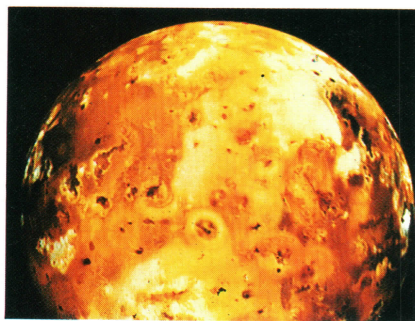
Still further out, another ancient catastrophe may have occurred in the neighbourhood of Neptune. One of Neptune's moons, Triton, revolves around its parent planet the 'wrong' way. Another Neptunian moon, tiny Nereid, moves along a path that is incredibly stretched-out. Not only this, but Pluto, the outermost planet, is not always the

furthest away. Its orbit is so elongated that, for 20 years in every 250, it skips inside Neptune's orbit.

All these strange orbits led some scientists to think that Pluto was once a moon of Neptune, and that there is an even bigger planet, beyond even Pluto, that has pulled Pluto and Triton out of their natural orbits. Planet X, if it exists, would be so far out from the Sun that it would only come into view every thousand years or so. There has been no sign of it as yet, but *Pioneers 10* and *11* are shortly going to leave the solar system. On their way, they may stumble upon the tenth planet!



Miranda, one of 15 known moons of Uranus, is scarred by huge ridges and craters. One canyon has walls 15 km high – twice the height of Mount Everest.

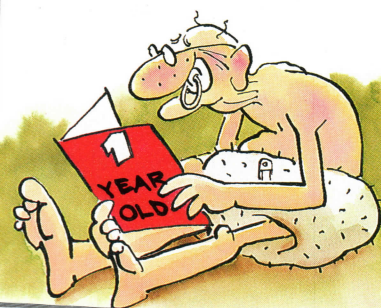


Io, which is slightly larger than our Moon, is torn by ceaseless volcanic activity, caused by the stresses of Jupiter's enormous gravity. Its entire surface is covered with reddish sulphur compounds.

Just amazing!

YEAR IN A LIFE

BIRTHDAY CANDLES WOULDN'T SELL VERY WELL ON PLUTO, SINCE BIRTHDAYS WOULD BE FEW AND FAR BETWEEN. THE PLANET TAKES SO LONG TO TRAVEL AROUND THE SUN THAT EACH OF ITS 'YEARS' LASTS OVER 247 EARTH YEARS.



Paul Raymond



- Q LIFE ON MARS?
- Q GIANT VOLCANOES
- Q TARGET PHOBOS

MARS

MAN'S NEXT BASE

SLOWED BY THREE GIANT parachutes, each as wide as a football field, the first manned craft to Mars descends through the planet's thin atmosphere. A few hundred metres above the ground, its retro-rockets fire, kicking up some of the rust-coloured dust that covers the surface. Seconds later, the capsule, with its eight-member crew, gently touches down on the mysterious 'Red Planet'.

Sometime in the 21st century, this historic event really is going to happen. Even now, scientists in the United States and CIS are urging their governments to co-operate in a manned mission.

Beyond the Moon, Mars is the next easiest world for humans to visit and explore. Not only that, but it may be an ideal place to set up a permanent base for scientific studies and for further investigation of the solar system.



Survival

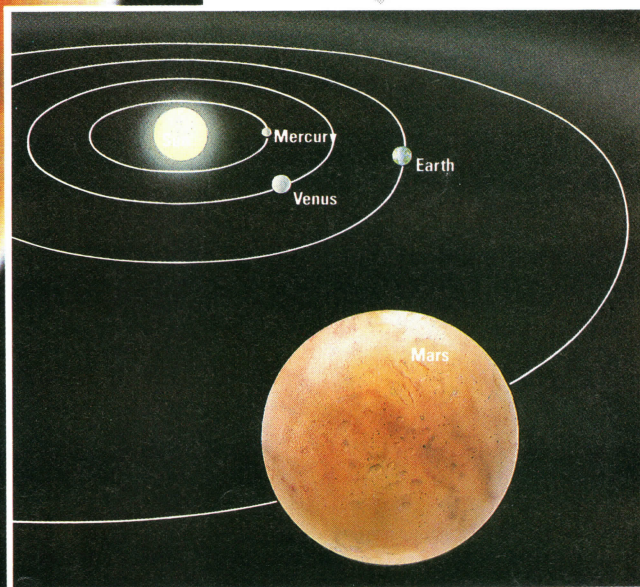
Apart from the Earth, Mars is the friendliest world we know. Its thin carbon dioxide atmosphere is harmless (though not life-supporting), and, with an average surface temperature of minus 23°C, Mars is generally no cooler than the Antarctic in winter.

Even so, the first explorers will need plenty of protection from Martian conditions. Spacesuits will be vital because the atmosphere is so thin that, by Earth standards, it is a near vacuum.

There is no chance that Mars explorers could survive in it. Even if it consisted of pure oxygen, no-one could breathe Mars' air. Our bodies require a much greater pressure of

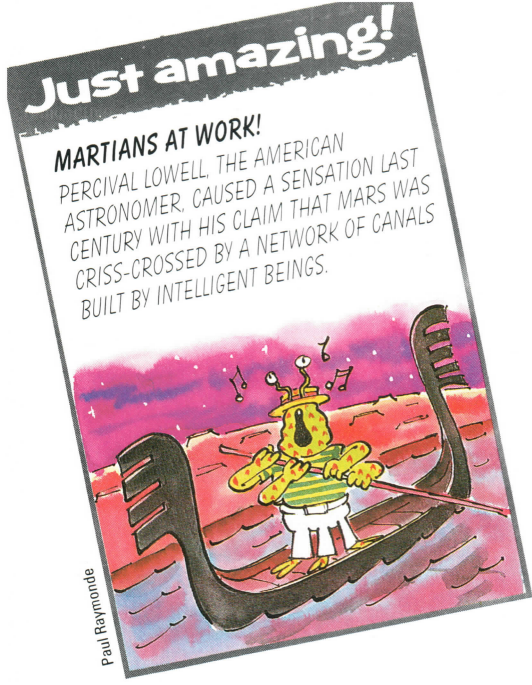
Mars is the fourth closest planet to the Sun. The most Earth-like of the planets, it could become Man's first colony in space in the next century.

JPL/NASA



Pavel Kostal





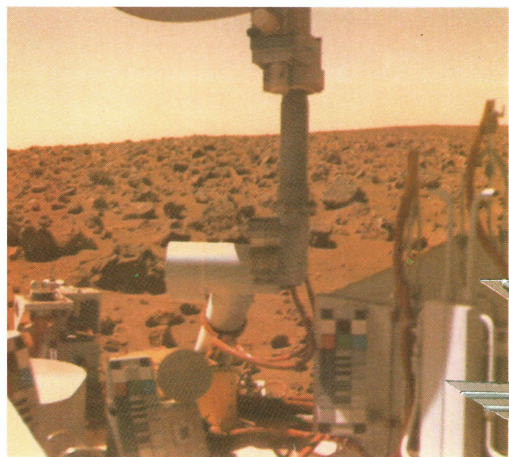
gas to breathe. One problem is that, as the atmospheric pressure goes down, so does the boiling point of a liquid. On a high mountain on Earth, water boils at only 70°C. On Mars, blood at body temperature would begin to boil almost immediately.

But even in their cumbersome spacesuits, the explorers will find that they can move around just as easily as they can on Earth. This is because Mars' surface gravity is much lower. You would weigh only 38 per cent of what you do on Earth. A future Mars Olympics would quickly set its own records for athletics.

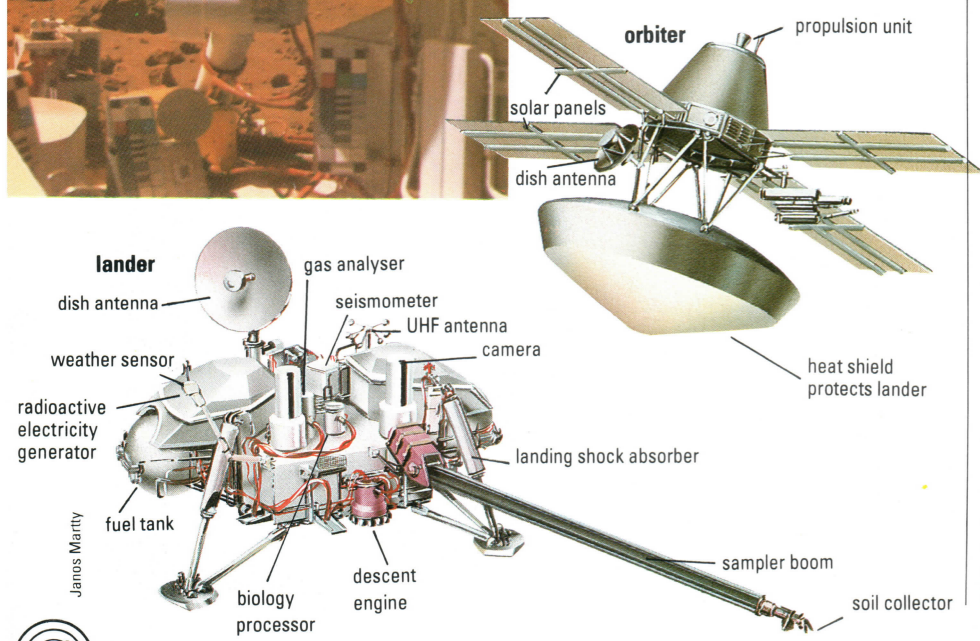
On Mars' surface, everything is

MARS MISSIONS

Launched	Nation	Probe	Achievements
1964 28 November	USA	Mariner 4	Fly-by mission. Sent back pictures of Martian surface and data on its atmosphere.
1965 18 July	USSR	Zond 3	Successful communication test with spacecraft crossing Mars orbit.
1969 25 February	USA	Mariner 6	Fly-by pictures of surface showed Moon-like craters.
1969 27 March	USA	Mariner 7	Fly-by mission. Sent back pictures of surface.
1971 30 May	USA	Mariner 9	Orbited Mars and transmitted hundreds of photographs of Mars and its satellites, together with much other data.
1973 25 July	USSR	Mars 5	Orbited Mars and returned photographs of surface and data on atmosphere.
1973 5 August	USSR	Mars 6	Returned atmospheric data, but contact with landing craft lost just before touchdown.
1975 20 August	USA	Viking 1	First soft landing on surface and first pictures from surface.
1975 9 September	USA	Viking 2	Soft landing. Pictures transmitted from the surface.
1988 7 and 12 July	USSR	Phobos	Two spacecraft sent to study Mars and land on its moon, Phobos. Contact with one craft lost <i>en route</i> and the other after arrival at Mars, March 1989.



Two US Viking spacecraft were put into Mars orbit in 1976. They ejected lander capsules, which parachuted to the surface to test the soil and atmosphere and send back photographs. The Viking 2 view shown here was beamed back via the radio dish antenna (top).



red. Even the sky is tinged pink, especially low down, near the horizon. This is because Mars is covered with fine red dust, so light that it hangs in the air.

The red colour is caused by iron. Just as rust is red, so the soils of Mars, with a significant iron content, are red. This same soil covers the entire planet.

A windy wasteland

Mars explorers will have to become used to the red wasteland. The surface is boulder strewn, but across this blows a thin wind, which is capable, over the centuries, of wearing down the rocks. And because the air is thin, the wind can blow much faster (in the same way that water flows faster than oil).

So particles of sand can be picked up and whisked high into the air. Even from Earth, observers with backyard telescopes can gaze at huge dust storms, sometimes covering the whole planet for weeks at a time.

Dust could be a major irritation for Martian explorers as it could get everywhere. Things will have to be specially dustproofed, because the dust will undoubtedly find its way into the living quarters on people's

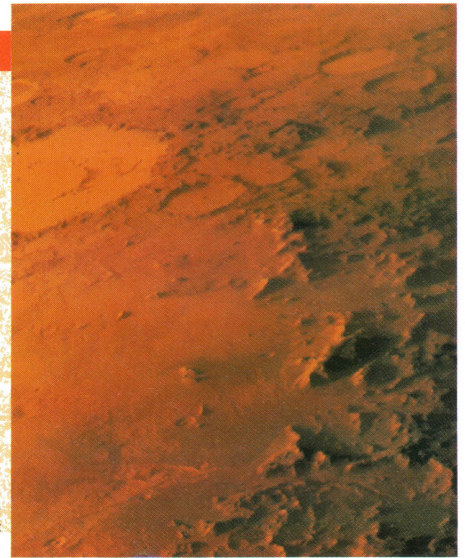
PROFILE

MARS COMPARED WITH THE EARTH

On Mars, a day lasts about the same time as a day on Earth. But, in most other ways, Mars is quite different to our planet.

Measurement	Mars	Earth
Diameter at equator	6,786 km	12,756 km
Distance from Sun (mean)	227 million km	149 million km
Mass	0.107 Earth mass	1 Earth mass
Volume	0.15 Earth volume	1 Earth volume
Density	3.9 g/cubic cm	5.5 g/cubic cm
Gravity at surface	0.38 Earth gravity	1 Earth gravity
Time to rotate on axis	24 hr 37 min 23 sec	23 hr 56 min 4 sec
Time to orbit the Sun	686.98 Earth days	365.26 Earth days
Number of moons	2	1

NASA



boots, just as lunar soil did on the Apollo missions.

Imagine that you are in the first manned spaceship to land on Mars. Out of the window you would probably see sand dunes caused by the wind-blown dust. Two American Viking probes sent back pictures of just such a view in 1976.



Martian landscapes

You might be lucky enough to be able to explore the amazing surface of Mars. There are volcanoes, including the largest known in the solar system, Olympus Mons. No-

one knows if they are still active. There are chasms, the largest of which, the Valles Marineris, would dwarf the Grand Canyon.

These chasms seem likely to hold Mars' most fantastic secret — for they were apparently cut by vast rivers of floodwater. Yet Mars is now drier than any Earth desert. One of the prime tasks of the early explorers will be to discover if reserves of frozen water still exist deep below the Martian surface, as most experts believe. One thing that the explorers won't find, however, is the famous canals. The long,

The flat Argire crater and its surrounding mountains were formed when a huge meteorite smashed into the surface.

straight features seen by astronomers from Earth are now thought to have been an illusion. No real features on Mars tie in with their supposed positions, so the idea of intelligent Martians is now regarded as science fiction.

A trip to one of the poles would take you to the polar caps. There is an icy cap at each pole, but they are different from each other. The northern cap is probably water ice, like Earth's, but the southern one is more likely to be frozen carbon dioxide — dry ice. Both increase in size in winter, then shrink as summer returns. This constant freezing and melting has created weird ice cliffs. They may become one of the sights of the solar system.

Mars has seasons just like Earth, but the year is about twice as long as ours. One thing that explorers will find familiar on Mars is the length of the day. It is very similar to our own, 24 hours and 37 minutes long, providing an almost ideal cycle of light and dark for both humans and plants grown for food. But before people go to Mars, we must first learn more about the planet.



Target: Phobos

In 1988 two probes were launched by the former Soviet Union with the intention of landing on Phobos, the larger of the two moons of Mars. It is thought that Phobos could be an important source of raw materials and water for astronauts next century. Contact with both probes was lost before landing on Phobos so they were unsuccessful, but several other Mars probes are already planned.



Mars Observer

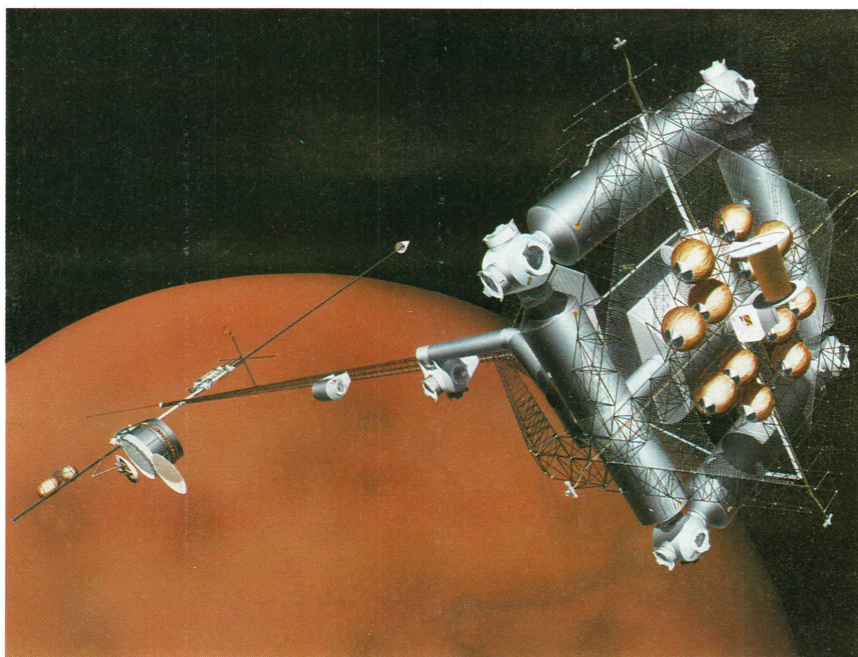
In August 1993, after an 11-month trip, NASA's Mars Explorer spacecraft will go into orbit around the red planet, circling from pole to pole at an altitude of less than 400 km. The Mars



Man's first Mars landing could be within the next 25 years. The explorers will first have two years of tedium, cooped up in their spacecraft during the journey, but will then transfer to the lander craft, shown here, for the descent. Giant parachutes are needed to slow the lander in the thin air, then retro-rockets fire to give a soft touchdown.

Mike Saunders





A US space station like this may be put into orbit around Mars. The station will be used as a base for mining and manufacturing activities on the Martian moon Phobos and for exploration voyages to the surface on Mars.

Observer craft will photograph the planet's surface features, study the composition of its rocks and follow its weather patterns throughout one complete Martian year, 687 Earth days. It is expected to find out more about Mars than all previous missions put together, and help pave the way for the first manned bases there.

While Mars Observer is still operating, a CIS mission called Mars 94 is due to land several small scientific stations on the planet in late 1995, and Mars Observer will relay data from these stations to Earth. A second CIS mission, Mars 96, will carry automatic Mars rovers and release balloons into the Martian atmosphere to study its weather.

Engineers at NASA's Jet Propulsion Laboratory in Pasadena have tested a Mars rover of their own, called Rocky, that could be driven over the surface of Mars by remote control from Earth, sending back pictures as it goes. Before humans ever leave for Mars, therefore, we will know what it is like to roam around on the surface. Rocky could be launched in 1996 as part of the Mars Environmental Survey (MESUR) Pathfinder mission.



Martian explorers

When will the first humans set foot on Mars? And who will they be? One possibility is that, some time next century, the CIS and the USA will work together to send a manned

spacecraft to Mars. The Mars ship would be assembled, in Earth orbit, from sections launched by the Space Shuttle. Then, with the crew on board, its engines would be fired to put it on to a curving path away from the Sun.

In a mission lasting two to three years, the astronauts would spend about six months on the Martian surface.

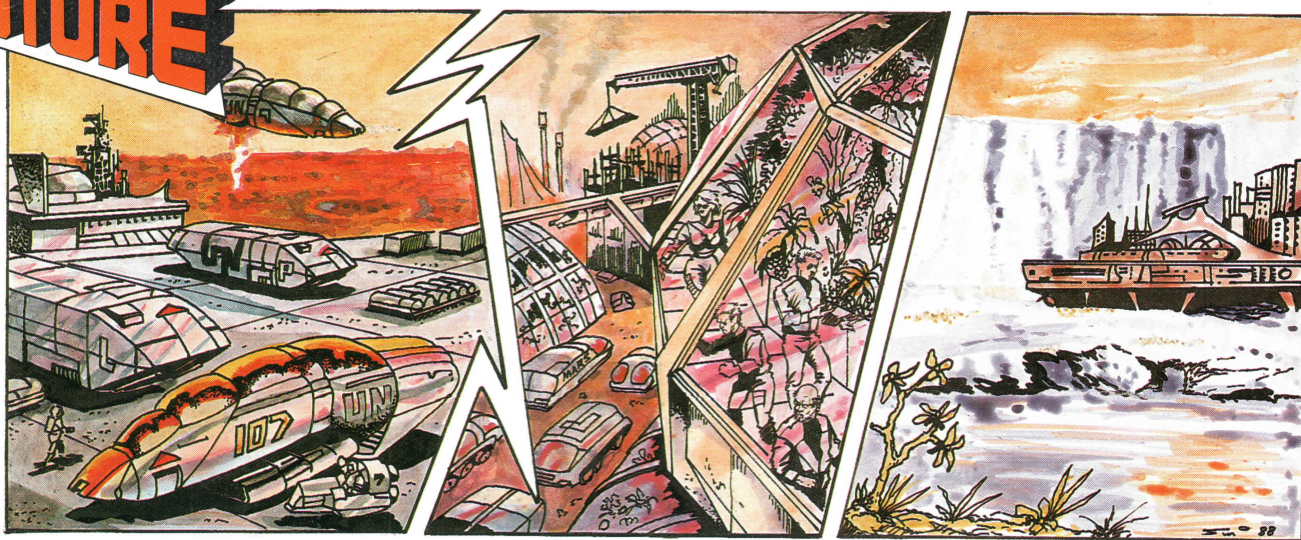
This means that the astronauts will have to create a true base, totally self-sufficient. They must be prepared for Martian extremes — the cold, the low pressure, the dust storms and the lack of protection from the Sun's radiation.

The best protection against radiation is to dig in. A metre or two of soil on top of the living quarters would be sufficient. NASA scientists are investigating various ways of doing this. One method would be to bury the quarters underground.

During their stay, those first explorers might travel many kilometres from their base camp in a special vehicle. And there are even plans for a special unmanned aircraft with huge wings and an enormous propeller. It could drone high over the fantastic canyons and mighty volcanoes, taking photographs. Meanwhile, the scientists would collect thousands of rock and soil specimens, drill for underground water, test the atmosphere, and search for traces of life.

INTO THE FUTURE

OUTPOST ON THE RED PLANET



▲ A regular spacebus service could ferry people from giant transporter spacecraft, linking Earth and Mars, to a permanent base on the Martian surface.

▲ Factories could make fuel, fertilizer, building materials and even oxygen from the Martian rocks. Food could be grown in giant greenhouses.

▲ Plants cultivated around the ice caps would absorb heat from the Sun. The ice would melt to form seas and, in time, Mars might become more like Earth.

Life of a

ON 24 FEBRUARY, 1987 AN event took place that set astronomers around the world buzzing with excitement. A star had just been seen to explode in a nearby galaxy visible from the southern hemisphere. It was the closest stellar blow-out, or 'supernova', to have occurred for nearly 400 years.

Stars rarely show any signs of change, even over many human lifetimes. A star like the Sun, for instance, can keep on shining more or less steadily for thousands of millions of years. Even so, stars cannot live forever. They are born, they develop and mature, and, eventually, they die – sometimes very spectacularly indeed.

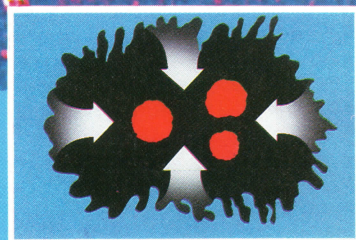
Drifting around our galaxy are vast clouds of gas and dust. The material in these clouds – mainly hydrogen gas – is spread out incredibly thinly. Yet over many mil-

lions of years, the gravity-pull of such a great billowing object may be enough to draw together the gas and dust particles into thicker, ball-shaped clumps.

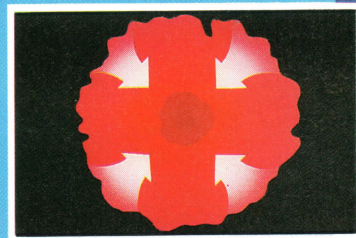
These clumps, or 'globules', then shrink further, becoming denser and hotter. Finally, the hydrogen gas at the heart of a globule reaches a temperature of over 15 million degrees C. Then it begins to pour out light and heat by nuclear fusion – the same process that powers a hydrogen bomb. A new star is born.

What happens next depends on the mass of the infant star. If this is especially high, then the star's core is squeezed very hard and the hydrogen gas there 'fuses' into the next heavier element, helium, at a tremendous rate. Despite starting off with a huge supply of hydrogen, a heavyweight star squanders its main fusion fuel recklessly. Within just a few million years, the stellar giant may start to use up other substances, heavier than hydrogen.

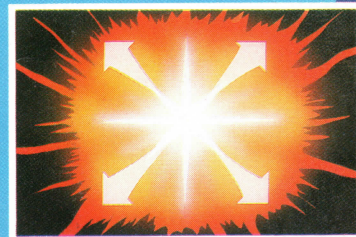
The Orion nebula, a cloud of gas and dust in which new stars are born. Colours in this picture are false. They have been applied to a black-and-white photograph to show clearly the boundaries between different shades of grey. Inside the cloud, giant stars form in a spectacular way, as illustrated below.



Interstellar dust and gases collapse inwards into clumps.



Energy generates heat at the core of the clump.



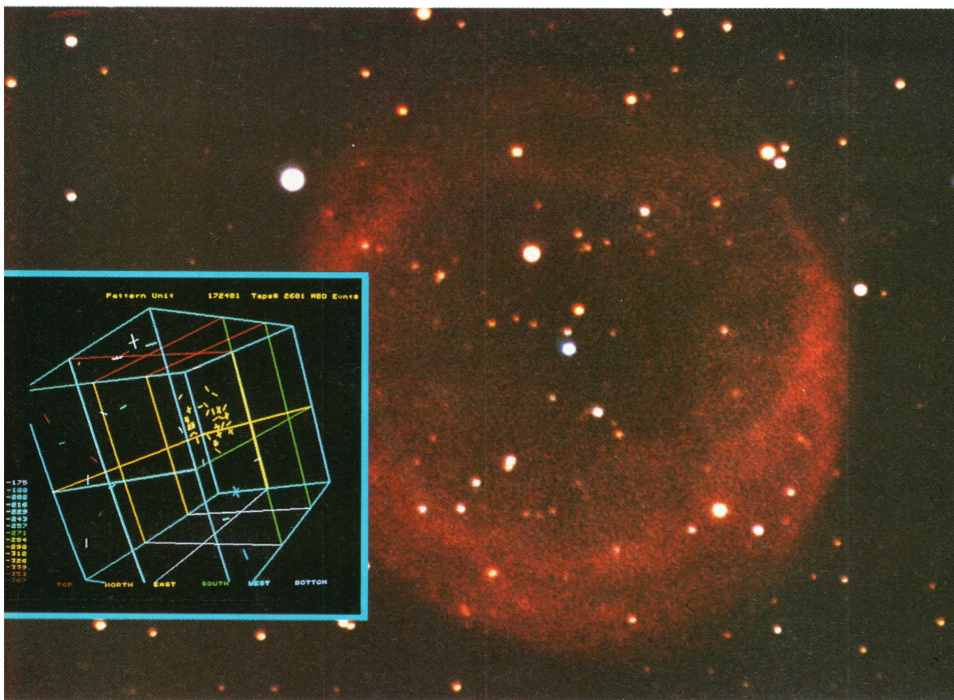
Residual dust blows away. The new star drifts off.



The Whirlpool galaxy has a clearly defined spiral form. Light from this multi-billion star collection takes 20 million years to reach Earth.

Ronald Royer/SPL Dr Fred Espenak/SPL





Inset IMB/SPL
California Inst. of Technology

SPL

Aquila planetary nebula – a spherical cloud of dust and gas left over from the death of a star. The computer display (inset) shows a neutrino particle received in 1987 from the supernova explosion of a supergiant star.

But these fuels, such as helium and carbon, are much poorer sources of light and heat.

Eventually, even the most massive of stars loses its ability to create fresh energy. Then the star's core can no longer support the enormous weight of the surrounding layers. In the wink of an eye, the dead core collapses while, at the same time, the star's outer parts are hurled into space at enormous speed. Even from far away, such a supernova blast is impressive.

Unlike the real stellar heavyweights, most stars, including our own Sun, will never blow themselves to bits. Even so, they can undergo surprising changes during the course of their life.

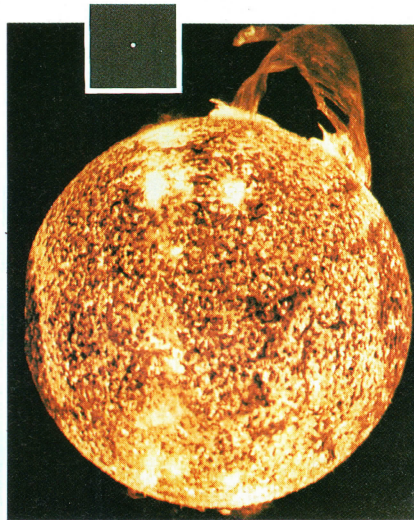
About five billion years from now, most of the hydrogen at the centre of the Sun will have been used up. For a while, the solar core will stop making energy and will shrink, becoming steadily hotter. At the same time, the outer layers of the Sun will slowly balloon out. As its surface swells and cools, the Sun will turn into a monstrous red giant.

Eventually, the Sun's shrinking core will become hot enough for helium to start fusing into carbon. In the millions of years that follow this, the bloated outer parts of the Sun will rise and fall like a great lung breathing in and out. Each time this

happens, some of the loosely-held gas from the upper layers will leak away into space. Bit by bit, the Sun will shed all of its giant atmosphere. The lost gas may collect as an enormous glowing ring or shell, known as a planetary nebula.

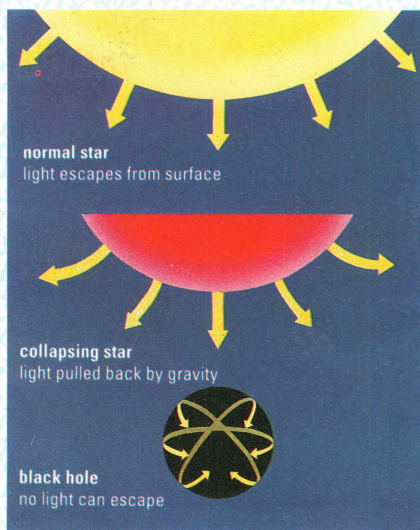
All that will be left of the Sun is its super-hot exposed core. No bigger than Earth and with a surface temperature of about 100,000 degrees C, the Sun will have turned into a white dwarf star.

Sometimes violently, sometimes gently, all stars throw some matter back into space. Over long periods of time, this cast-off material gathers up into new clouds of gas and dust from which future generations of stars will form.



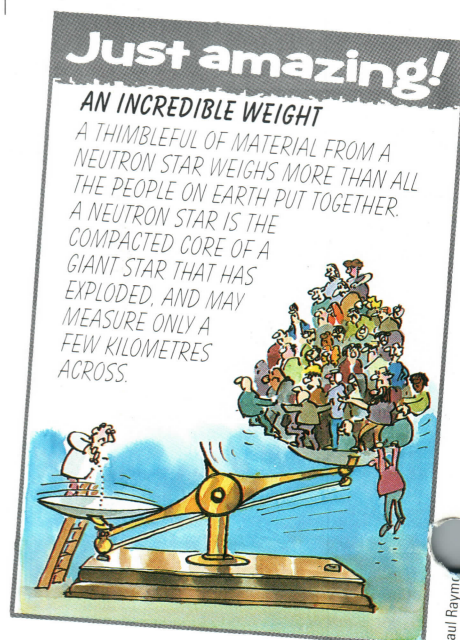
A solar flare from Earth's closest star, the Sun. This spectacular gas eruption extended more than 588,000 km from the surface. The Earth is shown at the same scale for comparison.

THE BLACK HOLE ENIGMA

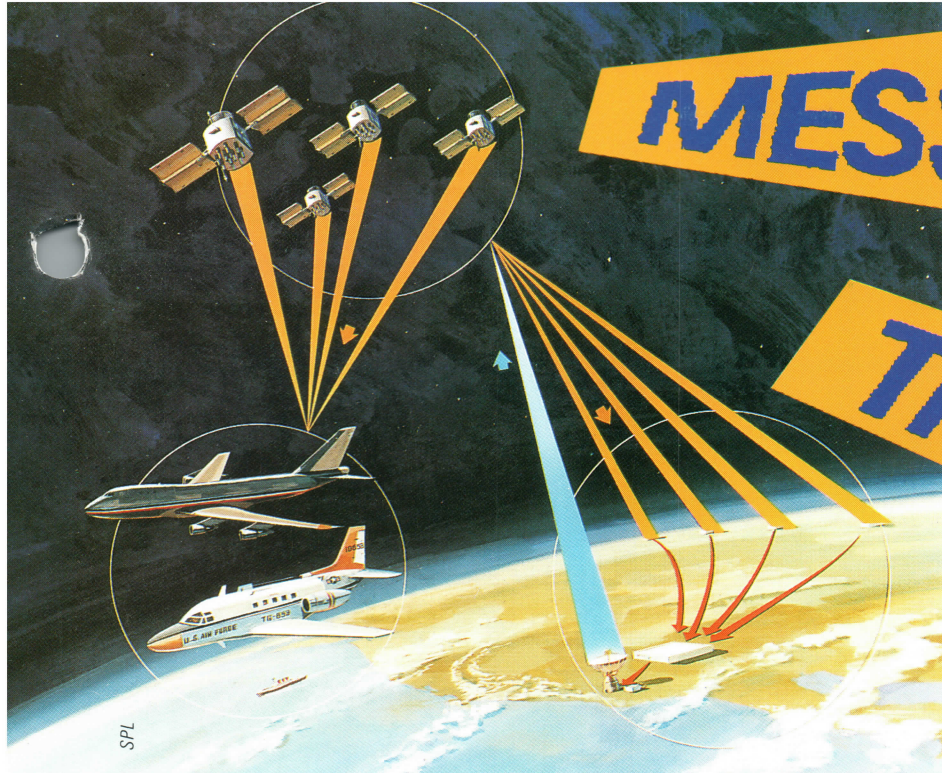


USAF/Berry Fallon Design

When a giant star blows up, most of its contents are thrown violently out into space. But the remaining lifeless core quickly shrinks. It may collapse until it is a solid ball of particles called neutrons. In extreme cases, the dead core becomes so compact that it forms what astronomers call a black hole. Its gravitational attraction is so powerful that it swallows up everything near it. Even light cannot escape from it, which is why it is 'black'.



Paul Reymond



MESSAGES FROM THE SKY

- Q SATELLITE TV
- Q WORLD-WIDE COVERAGE
- Q INTERNATIONAL DATA

TELEPHONE SOMEONE ON THE other side of the world and you will often notice little delays – less than a second long – in the conversation. It's not surprising. Whatever you say is being sent far out into space, bouncing off a communications satellite before returning to Earth to reach its destination.

Many such satellites now orbit the Earth, relaying countless TV signals, telephone calls and streams of computer data from one part of the globe to another.

Satellites also play a major role in navigation. Gone are the days when the stars and a compass were all you needed to cross the ocean. The increase in air traffic over the last few years means that it is absolutely vital to know the whereabouts of any aeroplane at any time. Today, satellite systems are in use that are

so accurate they allow the user to fix any point on or near Earth to an accuracy of ten metres.

Geostationary orbit

Most communications satellites have to remain in an exact spot over the Earth's surface so that receivers and transmitters on the ground can remain permanently pointed at them. They can only do this by moving in an orbit above the equator, which is 35,800 km high – about one-tenth of the distance to the Moon. This is called a 'geostationary' orbit, and once a satellite is in it, it takes exactly the same time to complete one orbit as the Earth does to spin once around on its axis (23 hours 56 minutes). This means that it seems to hang forever above the same point on the surface.

There are three main parts to a satellite communications system:

the transmitter, the receiver and the satellite itself. Information is beamed up to the satellite by large dish-shaped transmitting aerials known as ground stations. The message travels into space in the form of microwaves – short radio waves that can pass unhindered through the atmosphere.

With a small dish antenna of its own, the satellite gathers up the incoming signals. Then, almost instantly, it boosts the signals and transmits them back to a different part of the Earth. By the time the satellite transmission has arrived back at the ground it is no longer in



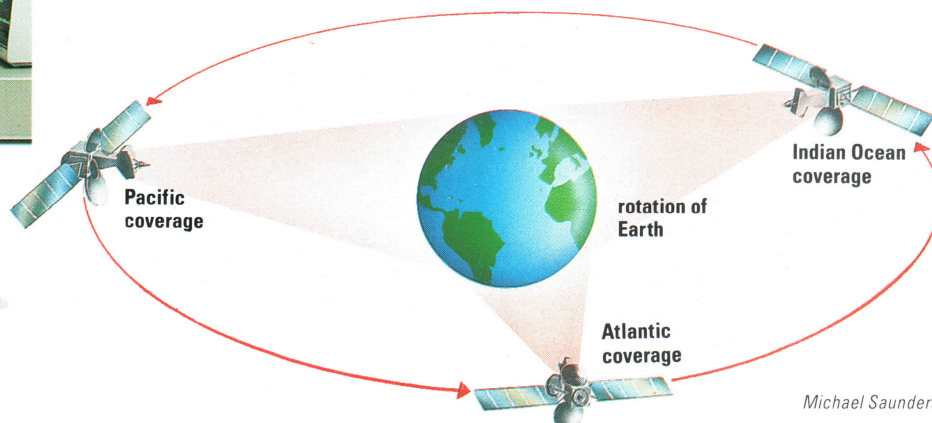
Zefa

Three satellites working together in geosynchronous orbit can provide world-wide coverage, thus allowing business data to be circulated, television programmes to be transmitted and telephone link-ups (above) to be available on a global basis.

A reconnaissance plane pilot can keep in touch with home base via satellite and receive instructions or navigational assistance throughout his flight.



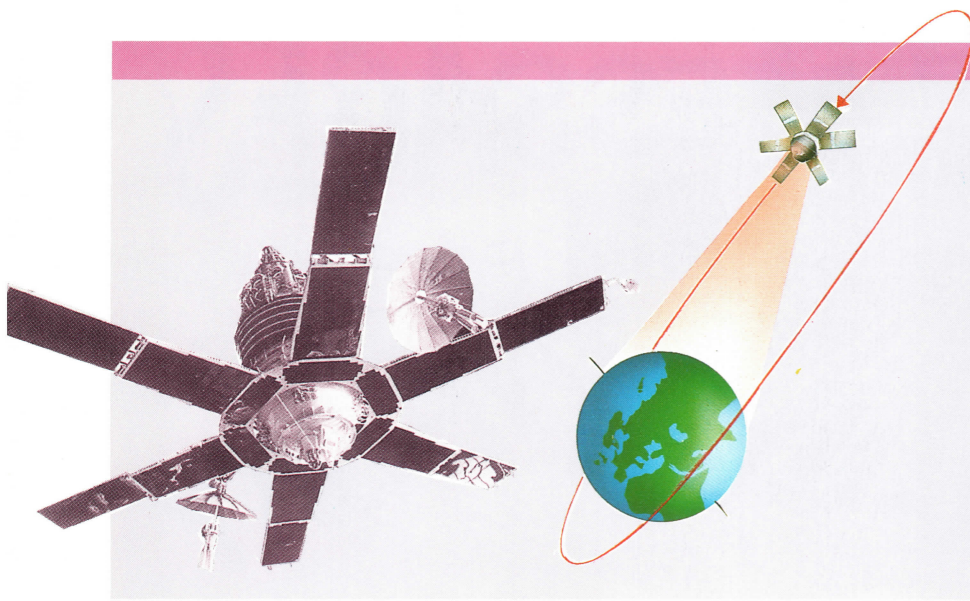
Barnaby's Picture Library



Michael Saunders



THE MOLNIYA CRAFT



When geostationary, a spacecraft can transmit to as much as 40 per cent of the globe, but it cannot reach high altitudes. This makes things difficult for northerly countries such as Russia. To solve the problem, the Soviets launched their Molniya series of communications satellites into enormously stretched out paths over the Earth's northern hemisphere. At its furthest point from Earth, a Molniya craft is 40,000 km away, and travelling slowly so that it remains visible from Russia for several hours at a time. A ground station can track the satellite and transmit or receive signals over this period.

Topham Picture Library

a narrow beam. Instead, it has fanned out over a wide area called the satellite's 'footprint'. Any suitable receiver within this footprint can then pick up the satellite's signal.

The receiving aerial also has to be dish-shaped to increase the strength of the weak signals coming from space. The microwaves coming down from the satellite strike the inside of the dish and are reflected inwards so that they all meet at the focus point, just above the centre of the dish.

Until a few years ago, the receiving dish needed to be huge. But because satellites can now amplify signals so much, modern receiving dishes are small enough to fix to the side of a house. These umbrella-sized aerials are now a familiar

sight, receiving dozens of TV channels from satellites such as Astra. Increasingly, though, cables are being used to bring the satellite signals from a central receiving dish to many houses in an area.

How it works

Seen from any point on the Earth today there are always several communications satellites above the horizon. Each satellite beams down many different signals at different frequencies. If you want to pick up a certain TV broadcast, your receiving aerial has to be pointed precisely at the right satellite, and be tuned into the correct frequency. The aerial then converts the incoming microwaves to electrical signals that are, in turn, fed to an ordinary TV set via a special converter.

Just amazing!

SHUTTLING TRASH

TWO THOUSAND LARGE PIECES OF SPACE JUNK AND COUNTLESS OTHER SMALLER PIECES ARE ORBITING EARTH. THERE ARE PLANS TO LAUNCH THE SHUTTLE AS THE FIRST GARBAGE TRUCK IN SPACE.



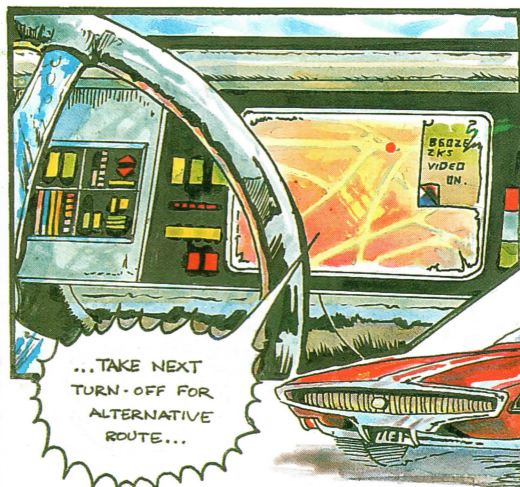
Paul Raymonds

INTO THE FUTURE

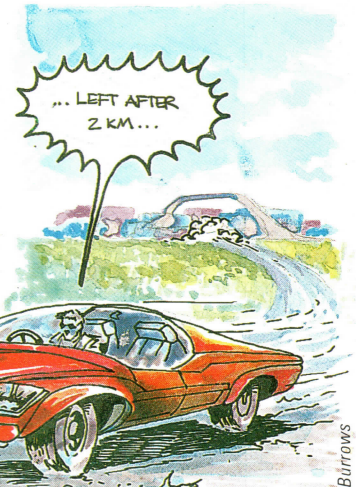
IN-CAR NAVIGATION



▲ Cars will soon have on-board computers, fitted as standard, which will be able to pick up signals from navigation satellites orbiting the Earth.



▲ The computer will have a complete map stored in its memory, and will be able to calculate the car's position, and the distance from its destination.



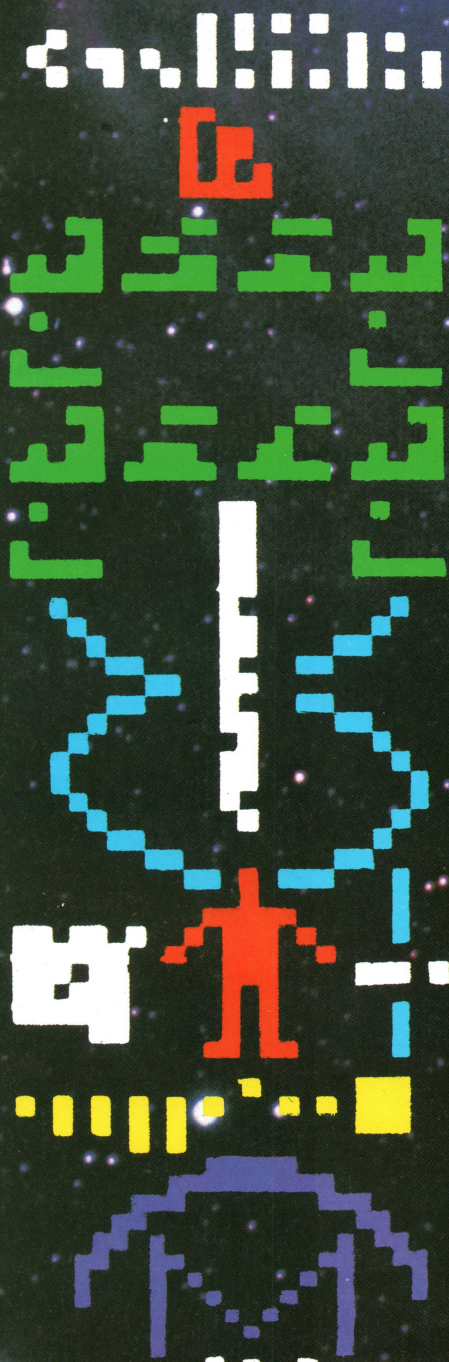
▲ A synthesized voice will then give the driver precise directions for the quickest route to follow, even taking into account how to avoid traffic jams.

Alan Burrows

- Q COMMUNICATING IN SPACE
- Q EAVESDROPPING ON STARS
- Q BEAMING MESSAGES

IN SEARCH OF

ET



DR TOM McDONOUGH, AN astrophysicist at the California Institute of Technology, is waiting patiently for a long-distance call. If it comes, it will have taken years to arrive and will have crossed trillions of kilometres of empty space. It will be the most stupendous event in human history – a message from an alien race among the stars.

At present, several experiments are going on around the world to try to communicate with extraterrestrials using radio signals. Some, like Dr McDonough's, are attempts to eavesdrop on the stars for alien messages that may be coming from planets orbiting them. Others involve beaming out signals from Earth to let anyone who may be listening know that we are here.

How many intelligent races are there 'out there' that we might be

A coded pictogram, containing information about life on Earth, was transmitted by the Arecibo radio telescope in 1974. The pictogram was formed by some 1,679 pulses arranged into a grid 23 characters wide by 73 characters deep.





The radio telescope at Arecibo in Puerto Rico is built into a natural bowl-shaped valley and has a 300-metre diameter. It is powerful enough to communicate with another radio telescope on a planet anywhere in our Galaxy.



South American Pictures

The Nazca drawings – giant figures scratched out on the desert at Nazca in Peru – are one of the great mysteries of the world. They show various animals, and may have been meant as a sign to the gods of the ancient Peruvians – an early form of attempted interstellar communication, perhaps. Photographs of unidentified flying objects, such as this one (inset), supposedly seen hovering over a football stadium in Colombia in 1979, are easily dismissed as hoaxes.

able to contact? The simple answer is, no one can be certain. Until scientists find just one example of life beyond the Earth, we cannot be sure that there are any extraterrestrial beings.

One of the first people to mount a search for alien radio messages was the American astronomer, Frank Drake, in 1959. He wrote down a formula for calculating the number of technological civilizations in the galaxy. This took account of factors like the fraction of stars with planets, the fraction of suitable planets per planetary system, and the fraction of planets where life arises. However, the formula gives answers that are only as good as the estimates put in by individual scientists.



Alien broadcasts

Unfortunately, listening for extraterrestrial messages is not as simple as tuning into an ordinary radio station. Not only are there billions of stars to choose from, but there are also billions of different radio fre-

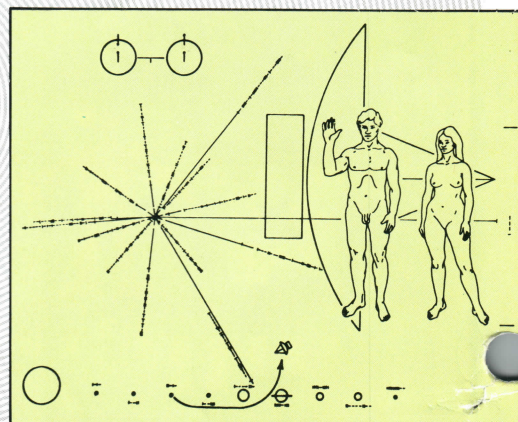
quencies at which an alien race might choose to broadcast.

Today, major advances in electronics have greatly speeded up the quest for E.T. Instruments like the giant radio dish at Arecibo, in Puerto Rico, have been linked to a special new device known as a multichannel spectrum analyzer. While the Arecibo dish is pointed at any given star in its search for alien messages, it tunes in to 27,000 different frequency bands. The analyzer linked to it then breaks each band into 74,000 channels and, using a computer, decides if each of these is broadcasting static, natural signals, or artificial signals. It also has to work out whether artificial signals come from some nearby man-made source, or from deep space.

The prospect for success is improving all the time as new, faster analysis equipment is developed. According to Dr McDonough, 'there is an excellent chance that by the year 2000 we will find the first indisputable proof of another civilization in space'.

INTO THE UNKNOWN

Engraved plaques were carried by the *Pioneer 10* and *11* space probes to Jupiter, both containing messages devised by the well-known astronomer, Carl Sagan. Sagan was convinced that the information, written in scientific language, would easily be interpreted by any civilization clever enough to intercept one of the probes. He also believed that the most difficult part of the message for an alien to understand would be the male and female figures. But he thought that their oddity would suggest they were biological and not technological.



Just amazing!

ANYBODY OUT THERE?

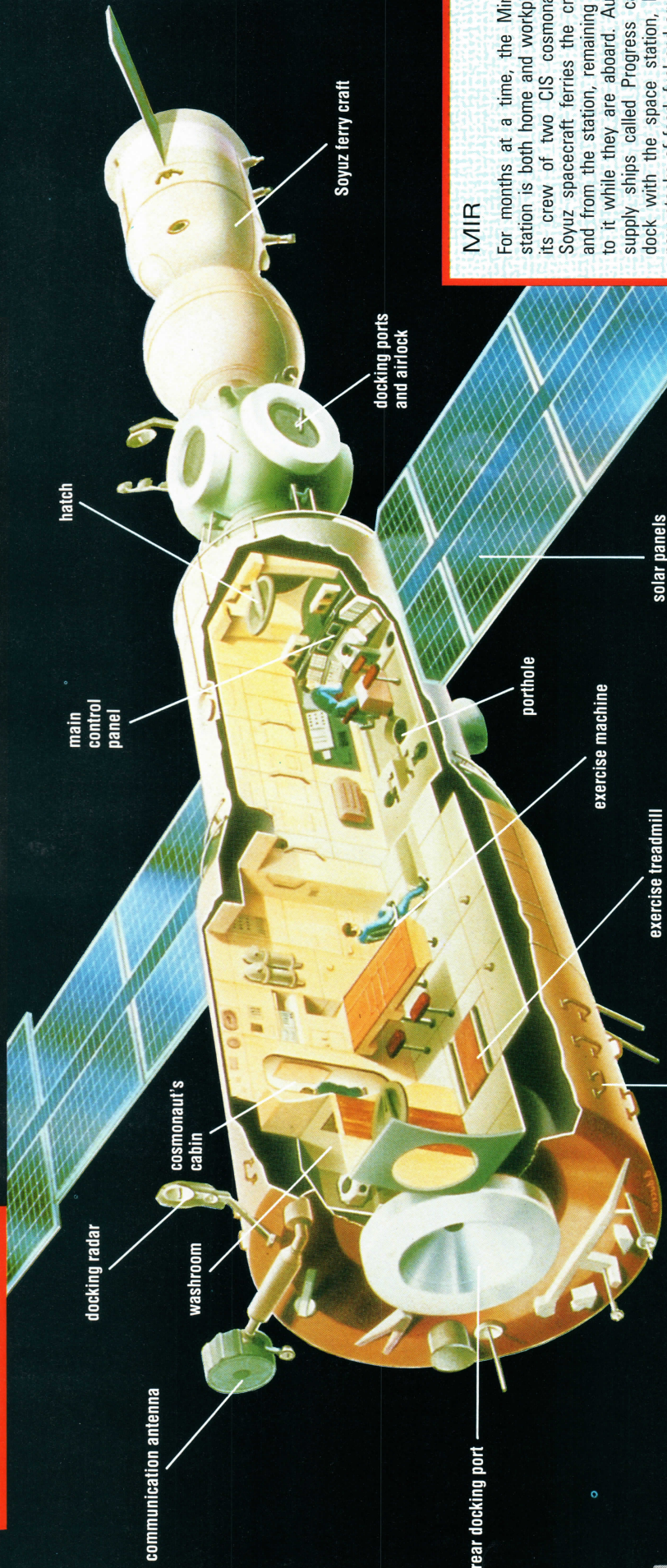
TALKING TO ALIENS INVOLVES VERY SLOW CONVERSATIONS. IN 1974, A MESSAGE WAS BEAMED TO THE STAR CLUSTER M13, BUT ANY REPLY WON'T REACH EARTH UNTIL 50,000 AD.



Paul Raymond

A HOME IN SPACE?

- ARTIFICIAL GRAVITY
- FARMING IN SPACE
- RADIATION SHIELDING



MIR

For months at a time, the Mir space station is both home and workplace for its crew of two CIS cosmonauts. A Soyuz spacecraft ferries the crews to and from the station, remaining docked to it while they are aboard. Automatic supply ships called Progress can also dock with the space station, bringing new stocks of food, fuel and equipment. Other crews can visit the space station. Visitors to Mir have included Helen Sharmon, the first Briton in space, who spent a week aboard in May, 1991. Additional sections docked to Mir provide more working space in which to carry out experiments in the weightless conditions of orbit. The two cosmonauts can leave the space station through a hatch to carry out repairs to the station and its wing-like solar panels that generate electricity. Experience aboard Mir has shown that humans can live in space for long periods without harm.

naut is the body's inability to produce calcium for the bones. Calcium loss can be as high as two per cent in a month. At that rate, a long space trip could permanently cripple a space traveller. For those carrying out a tour of duty at a space station, long periods of zero gravity would be intolerable. Therefore space stations will mimic Earth's gravity.

To do this, they will rotate, producing centrifugal force at the outside edge. A practical design for such a rotating model is a circular

as a service by scientific establishments which pay for various experiments to be carried out in space. Industry provides the money to set up factories in space for special manufacturing processes designed to take advantage of the lack of gravity. Eventually, this will lead to the establishment of huge, permanently staffed space stations.

Away from Earth's gravity, one serious disadvantage for the astro-

SPACE EXPLORATION IS hugely expensive — it cost \$25 billion to put the first man on the Moon. But now that a great deal of expertise has been gained in space technology, the space agencies are earning money by providing services to military, scientific and industrial organizations.

Placing communications satellites in orbit is frequently demanded





Space laboratory work means spending many hours carrying out routine checks. Leisure pursuits are important to combat boredom.

constantly recycled, for drinking and for reconstituting dehydrated foods. Filtration plants will recycle water, urea and carbon dioxide from the space-travellers' body wastes to produce purified water and oxygen.

Water would also be produced as a byproduct of the fuel cells, which would create electricity by combining hydrogen and oxygen.

Food production

For long, unserviced flights, food will have to be synthesized in small micro-biological units. On a large space station, with artificial gravity and climates, food could be produced by growing plants. It would be more economic to grow the plants in solutions of nutrient, rather than in soil. Animals would be relatively uneconomic to produce for food, although some could be reared to add variety to meals. Home-grown items would be good for morale, but would be an expensive luxury.

Safety in space

Radiation is always a hazard in space, particularly at the time of major solar flares. These release high-energy protons capable of piercing simple shield systems. During non-flare periods the annual radiation dosage in space would be about 20 times higher than the US standard for maximum allowable background radiation on Earth.

continuous cylinder, like a thin doughnut.

A large, rotating, circular space station will provide an Earth-like environment, which could be enhanced with plants and trees, and even water lakes.

Practical problems

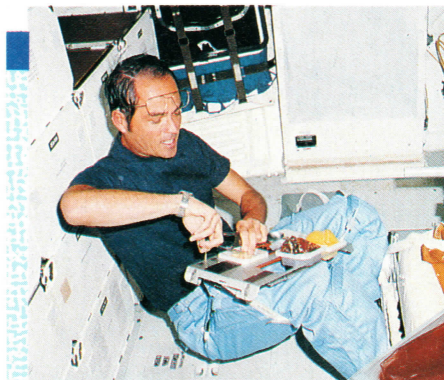
On spaceships and small space stations, where it is not practicable to counteract the effects of zero gravity, simple functions such as eating and going to the lavatory create major problems. Unless care is taken when eating and drinking, lumps of food and globules of liquid will sail uncontrollably around the cramped living space. Early space food included meals in squeeze-bags, which delivered nutritious sludges directly into the mouth via a tube. But these meals proved unpopular, so astronauts now have food that resembles what they would eat back on Earth.

In zero gravity conditions, special devices are necessary to collect the astronauts' solid and liquid wastes.

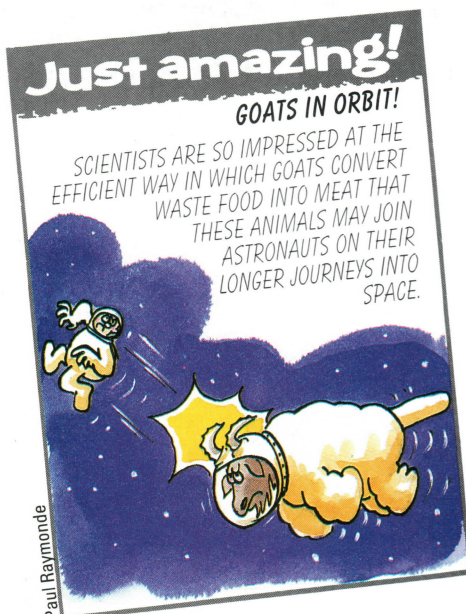
Space commodes are fitted with lap straps, as well as hand and foot holds, to keep the astronaut clamped securely to the close-fitting seat. Air jets and air suction move solid wastes down into the chamber, where they are fragmented by a rotating metal blade. After being dried, the wastes are stored for later analysis.

Urinating is achieved either via personal 'relief tubes', with different fittings for men and women, or through a unisex fitted cup. Urine is vented out into space, where it flash freezes instantly into ice crystals. Sometimes the vented urine builds up into bulky icicles, which have to be removed from the outlet port by means of an external robot arm.

On both large stations and small spacecraft, water will need to be



A typical daily meal on board an American spacecraft could include smoked turkey, mixed vegetables, cream of tomato soup, and strawberries. Peanuts and dried fruit can be eaten as snacks. Freeze-dried dehydrated foods can be reconstituted by squirting them with cold water from a gun connected to the food pack. A hot-water gun is available for making tea, coffee and cocoa. Drinks are sucked through a tube or squeezed into the mouth from a flexible plastic container.



SATELLITE

KILLERS

-  INTERCEPTORS
-  SPACE MINES
-  HIGH-ENERGY LASER

MILITARY SATELLITES ARE the long-range eyes and ears of the armed forces of several nations. If war breaks out, both sides will aim to destroy the other's military spy satellites with ASAT (anti-satellite) weapons.

Over three-quarters of all satellites launched are intended for purely military purposes. They relay military radio messages, eavesdrop on radio and radar signals, and take detailed photographs of troop and ship movements, airfields and missile bases. They can also detect and track enemy missiles, and they help ships and aircraft to navigate, and missiles to find their targets accurately.

Russia's main ASAT system is based on killer satellites, while the USA has concentrated on ASAT missiles. In the future, both countries will probably add laser and particle beam weapons to their ASAT arsenals.



Killer satellites

The Russian killer satellite system uses a version of the SS-N-9 missile to put an interceptor into orbit that can attack targets in orbits of up to 5,000 km above the ground.

The interceptor is put into a lower orbit than the enemy satellite, to allow it to catch up with its target. Once correctly positioned, it fires its engines to boost it into the target's orbit and then homes in on it, guided by radar or infra-red sensors. As soon as it is close enough, its high-explosive warhead detonates and destroys the target with a hail of shrapnel.



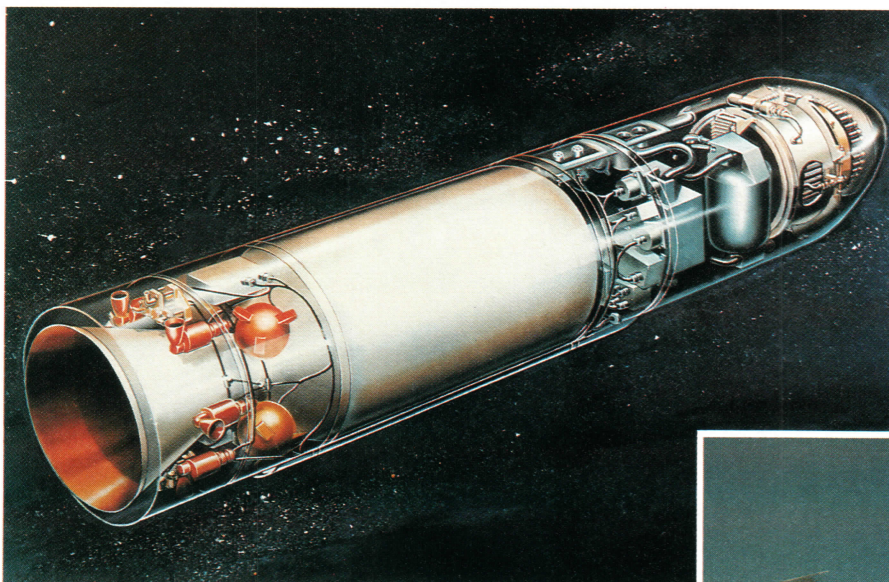
ASAT missiles

An alternative to using a killer satellite is to knock out enemy satellites with missiles launched either from the ground or from aircraft. Russia may have a ground-launched ASAT missile, developed from its ABM-1

A US ground-launched missile heads for the skies. These are capable of destroying satellites circulating in low orbits.

Hertz/Liaison/Frank Spooner Pictures





US Department of Defense/USAF

based. To prevent the beam from being spread and weakened by the protons colliding with air molecules in the atmosphere, it could be fired down the middle of a laser beam. The laser would ionize the air molecules, creating a 'tunnel' for the proton beam to pass through, uninterrupted towards its target.

The upper stage of the US Air Force's ASAT missile. The two-stage missile burns out, leaving the miniature homing vehicle (in front) to lock on to its target, which it destroys.

Galosh anti-missile missile, that is capable of destroying satellites in low orbits. The Americans have developed an air-launched missile.

The American ASAT missile, launched from a modified McDonnell Douglas F-15 fighter, is a two-stage, 5.4 metre-long missile carrying a device called a miniature homing vehicle (MHV).

To launch the missile, the F-15 accelerates in level flight and then climbs steeply, releasing the missile as it zooms upwards. After the first stage of the missile has burnt out and separated, the MHV continues upwards powered by the second stage and its infra-red sensors search for, and lock on to, the target satellite.

In the final phase of the attack, the MHV separates from the second stage and hurtles towards its target, steered by 56 tiny single-shot rockets. The MHV is only 33 cm long and 30.5 cm in diameter, and it carries no explosive warhead

The F-15 with an anti-satellite missile loaded can fly almost anywhere to intercept. The missile can be launched during a steep subsonic climb.

US Department of Defense/USAF



— it simply rams the target to destroy it. But at a collision speed of around 13 km per second, the impact is reckoned to be the same as a direct hit by a 155 mm artillery shell.

Beam weapons

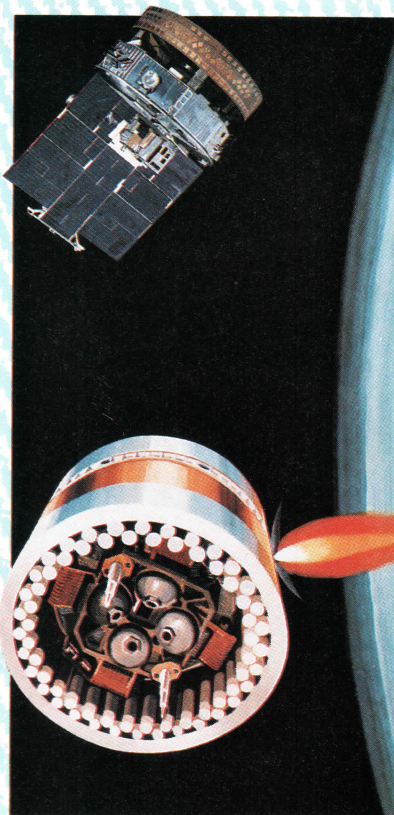
Much of the anti-missile technology being developed by the Americans for their Strategic Defence Initiative ('Star Wars') project, and by Russia for its own version of it, could be used against satellites.

High-energy lasers, ground-based or carried on aircraft or satellites, could blind a satellite's sensors, make it overheat and stop working or even physically destroy it. Photographic surveillance and weather satellites are especially vulnerable to laser attack, because they travel in low orbits and their downward-looking optical and infra-red cameras are easily blinded by lasers.

Future satellites of this type will be able to defend their cameras against laser attack. Radar sensors on the satellite will detect the tracking radar used to guide the laser, and activate systems that shield the cameras or tilt the satellite away from the direction of the laser beam.

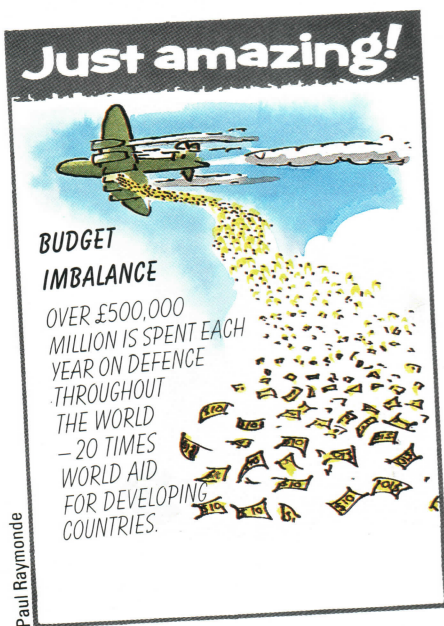
Particle beam weapons would use a beam of sub-atomic particles — protons — to destroy a satellite's electronic circuits. Because of the enormous amounts of energy needed to produce these proton beams (the Russian system is powered by small nuclear explosions), particle beam weapons would probably have to be ground-

ADVANCE WARFARE



US Department of Defense/USAF

Instead of killer satellites being sent up in the early stages of a war, they could be launched days, weeks or even years in advance and left in orbit close to their intended targets. These 'space mines' could then be commanded to destroy the enemy's satellites as soon as the first shots were fired.



Paul Raymond

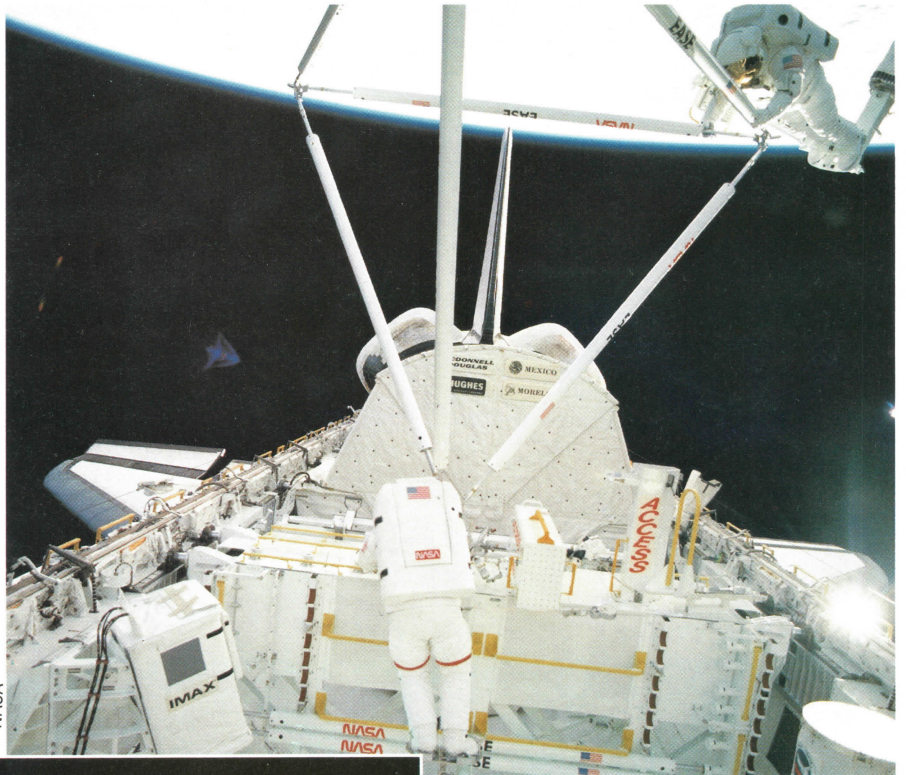


ASTROSTRUCTURES

- Q SPACE STATIONS
- Q WELDING IN SPACE
- Q MINING THE MOON

HUMAN BEINGS HAVE BEEN living and working in space for more than 30 years, but little construction work has been done there. However, in the mid-1990s, the building of the international Freedom space station will begin. Novel building designs and assembly methods have been developed for the hostile environment of space.

The largest orbiting space vehicle so far, Skylab, was launched in 1973 as a single unit. It consisted of the third stage of a giant Saturn V rocket, of the type that launched the Apollo Moon missions. What would have been the rocket's hydrogen fuel tank had been converted to living quarters, while the original oxygen tank below the crew



Space Shuttle astronauts in Earth orbit try out structure assembly techniques in weightless conditions.

The Freedom space station, an international project planned within the next decade, will have laboratory modules for studying materials, and plant and animal life under low-gravity conditions.

in October 1969. Now NASA has designed an automatic beam builder that would use welding to construct trelliswork beams. Ribbons of a graphite/epoxy resin compound coated with aluminium would be unwound from spools. Cross-pieces would be automatically cut and welded onto these. When a sufficiently long beam had been constructed in this way it would be cut off, and astronauts would attach it to the space station structure.

Materials such as the graphite/epoxy combination are used in space because they do not deform greatly under extreme variations in temperature, which occur on the sunlit and shadowed side of space stations and satellites.

Assembling structures in space

quarters was used to store waste.

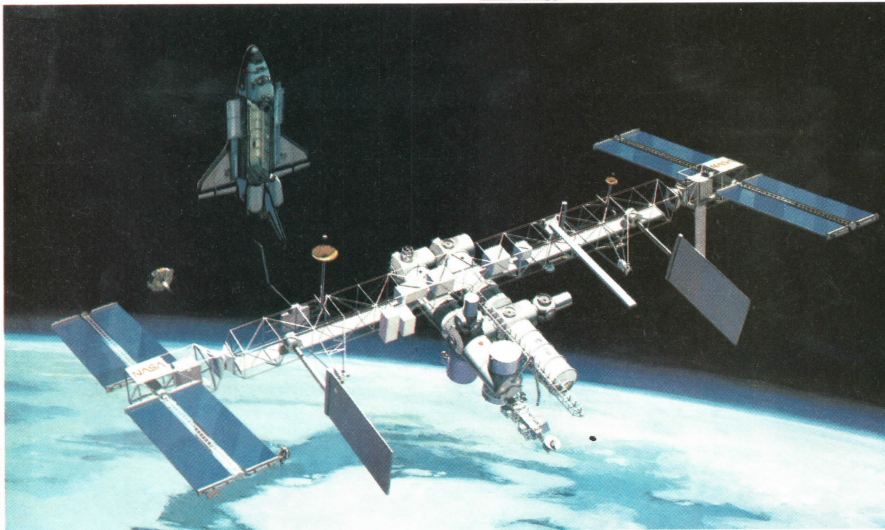
Assembling structures in orbit has great advantages over launching them ready-made from the Earth, as Skylab was. Because objects in orbit are weightless, they can be made very much larger than anything that could be carried up on a rocket. Also, they can be much more flimsy than a similar building on the ground.

The space station will be far larger than Skylab. It will be assembled from parts, or 'modules'. These

will not be converted rocket parts but specially built units, each carried into orbit in the cargo bay of a space shuttle. A long robot arm will haul each module out of the shuttle and 'clip' it on to the space station assembly by means of snap-on connectors.

Robot welders

Welding may be used in building the space station. The first experiments in space welding were made by the Soviet cosmonaut, Valery Kubasov,



NASA/ESA



may be done with the aid of robot arms like the 50 metre arm now used on the shuttle. The 'end effector' (hand) on the arm will be controlled by an astronaut on board the spacecraft.

Space mechanics

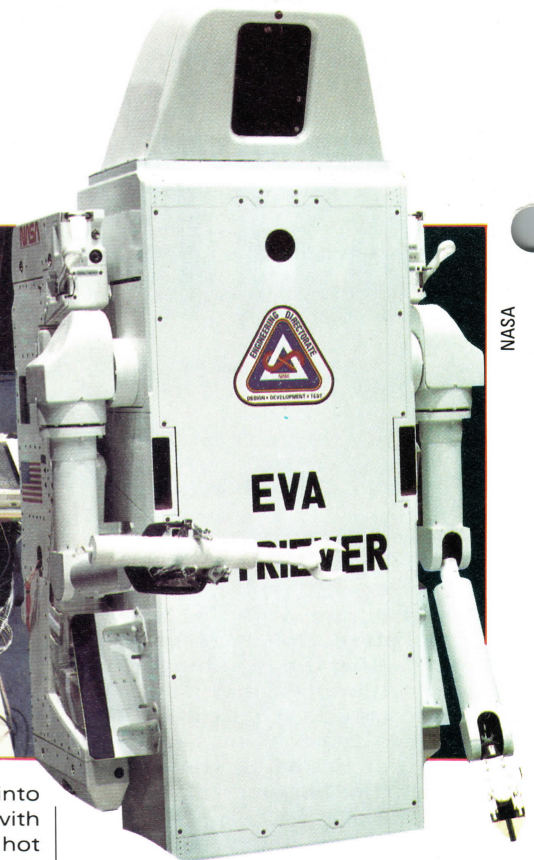
For other jobs it will be necessary for an astronaut to get as close as possible, so an EVA retriever ('extra-vehicular activity') will be used. The astronaut may ride on a 'manned remote work station', mounted on the end of the shuttle's robot arm. The worker might wear a spacesuit and be attached to the station by foot restraints, or he or she could be in shirt sleeves inside a pressurized 'hut'.

For yet other jobs the workers could be free-flying, by means of jetpacks worn on the back, or in pressurized work-stations that would be 'mini-spaceships'. However, robots may play a part in this area too. Already NASA is planning a free-flying robot worker called the EVA Retriever.

Space mission scientists test the human-sized robot called EVA Retriever. It will retrieve tools and other items accidentally allowed to drift away while working in space.



NASA



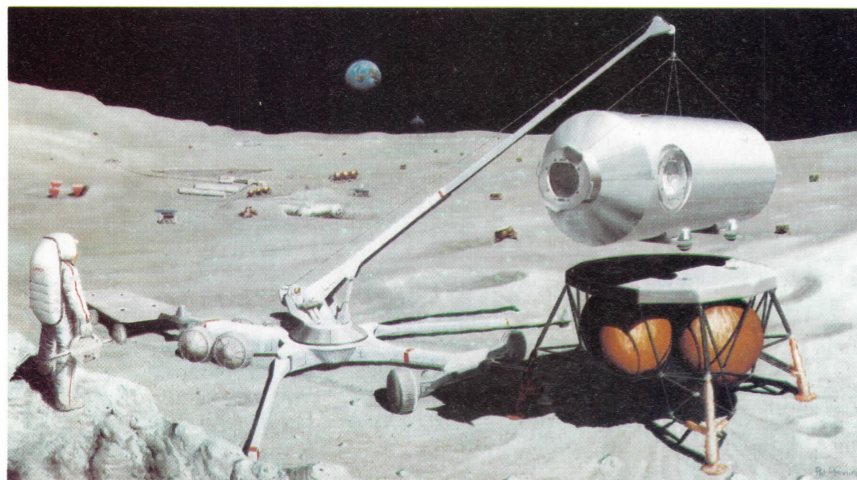
NASA

Moonbase

The US National Commission for Space recommended that America should start to build a permanent base on the Moon by 2005. It could be built from modules exactly the same as those used in the space

station. They could be set into shallow trenches and covered with soil to reduce the extremes of hot and cold and the threat of cosmic rays.

However, it would be much cheaper to make building materials on the Moon from lunar rock.

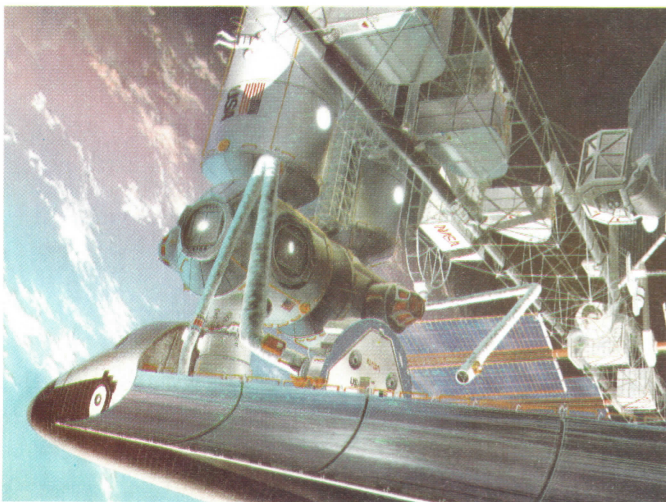


NASA

Already 40 grams of the precious rock brought back by the Apollo missions have been used to make tiny quantities of concrete. The experiments seem to have been successful.

There are plans to extract useful materials from the Moon rocks. Oxygen, for example, could be used to make rocket propellants and to supply air to the Moonbase.

A manned Mars colony may be started in the 21st century. It would be cheaper to transport materials from the Moon than from the Earth. But first the techniques of lunar mining and manufacturing must be mastered.



NASA

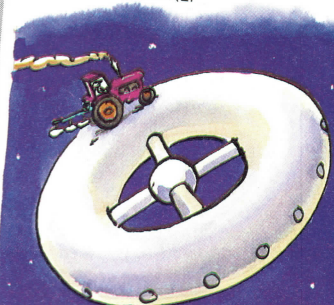
To start building on the Moon, modules delivered by lunar landers will be unloaded by crane and hauled to the site.

Docking a space shuttle and unloading equipment from its cargo bay will become a routine operation when space stations like this have been constructed in Earth orbit.

Just amazing!

ARTIFICIAL WORLDS

FUTURE SPACE COLONIES WILL BE SELF-SUPPORTING COMMUNITIES LIVING IN HUGE ROTATING RINGS, SPHERES OR CYLINDERS WITH THEIR OWN INDUSTRIES AND AGRICULTURE.



Paul Raymonde

DEEP IN SPACE, A GIANT telescope locks on a distant star. The signals analysed back on Earth indicate planets are orbiting. Where there are planets, there could be life.

This is just one of the discoveries that could be made by a new generation of Space telescopes about to be put into orbit round our planet. The Hubble Space Telescope, launched in 1990 via the Space Shuttle, heralded a new age of knowledge of the Universe, despite some early technical troubles.

Putting a large telescope into orbit is very expensive – so why not use the big telescopes on Earth to tell us about distant objects in the sky? The simple answer is that the atmosphere filters out a great deal of light. It is constantly moving, making images in telescopes wobble and lose definition.

Ground telescopes

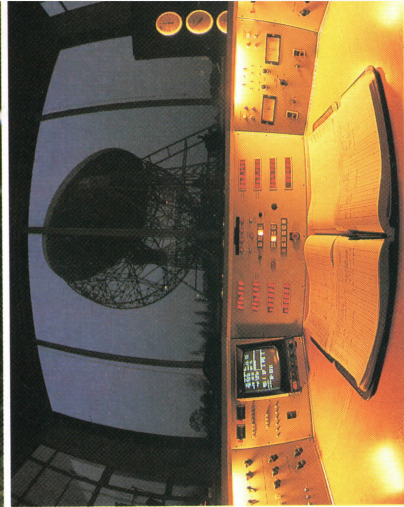
Since people first looked through simple refracting telescopes hundreds of years ago, the race has been on to build bigger and better telescopes. Lately, all the really big 'scopes have been reflecting telescopes.

These are usually sited a long way from the bright lights of cities, and high up on a mountain where the air is thinner and calmer. Very few giant observatory telescopes can be looked through directly. Most are designed to produce images that are recorded photographically or electronically. Many use image intensifiers to amplify light far fainter than the eye can detect.

A computer-enhanced optical photograph of spiral galaxy M33 only 2.4 million light years away from our own Milky Way

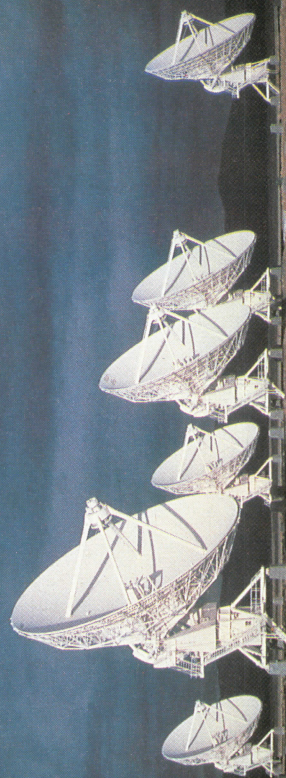
Dr Jean Loree SPL

THE LIGHT WINDOW SPACE TELESCOPES VERY LARGE ARRAYS



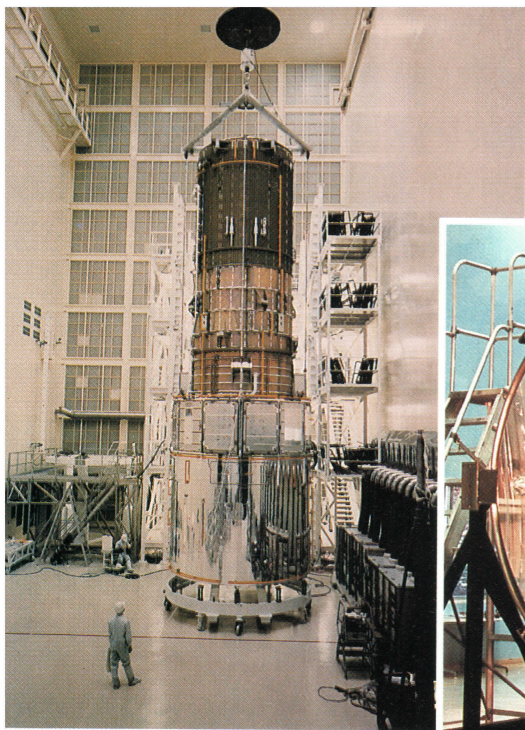
David Parker/SPL

Arrays of radio telescopes may be connected to others miles away to create VLAs (very large arrays)
The world's first giant radio 'scope is visible through the window of the control room at Jodrell Bank, England (inset right).

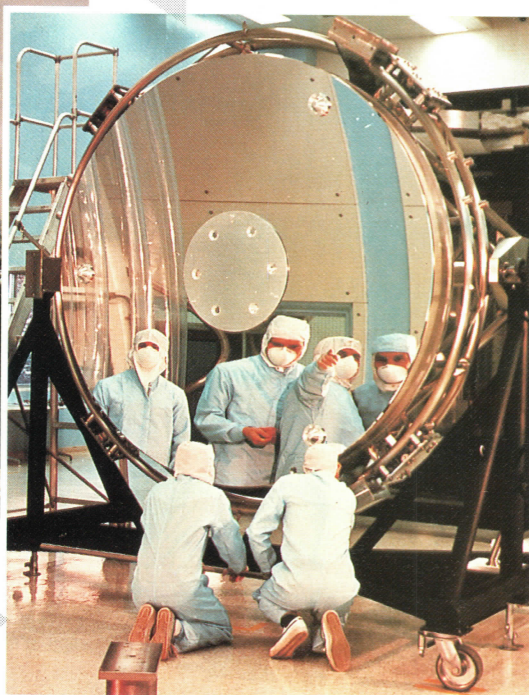


Tony Stone Photo Library, London





The Hubble Space Telescope, ready for lift off. It should see seven times further into space than astronauts have ever seen.



The mirror from the Hubble 'scope has a special reflective surface. Technicians must wear masks and gowns to ensure absolute cleanliness – any speck of dust may mar the surface.

The telescope with the single biggest mirror is at the Mount Pas-tukhov Crimean Observatory in the USSR. Its mirror is 6 metres across, compared to the 5.1 metre mirror of the telescope at Mount Palomar in the USA. However, the Palomar mirror is a bit better because the Crimean mirror is so big it actually distorts under its own weight.

Several new ground-based telescopes are planned, using new

glass-moulding technology. One of these, at Mount Graham in Arizona, will have two giant mirrors – each 8 metres across giving the light gathering power of a mirror 11.3 metres across.

Some telescopes work in the infra-red section of the spectrum and need an array of special detectors. A new detector is being installed at the Mount Lemmon 1.5 metre reflecting telescope. It has 16,384

The River Nile in flood, seen from Space. Orbiting telescopes can also be used to examine the Earth – to predict weather and natural disasters and to reveal resources.

A digitized, colour-coded image of an exploding star, or supernova, from the International Ultraviolet Explorer satellite.

photodiodes, in an array 128 by 128, made from a compound of cadmium, mercury and tellurium. This allows astronomers to take pictures of the infra-red emissions from whole galaxies.

Orbiting telescopes

But there are limits to what can be seen through the Earth's atmosphere, even when the telescope is sited near the top of a very high mountain above most of the air. This is where orbiting telescopes come in.

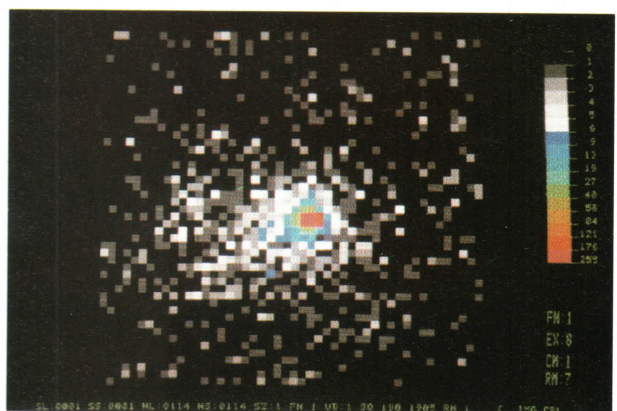
Telescopes in space can pick up radiation in the X-ray, ultraviolet, infra-red and long wave radio wavelengths that cannot be detected on Earth. X-ray telescopes, such as those in the MIR and Ginga satellites, detect X-rays that are generated by gas falling into super-dense neutron stars. Other radiation, especially those at very short wavelengths, are produced in quasars and in the heart of galaxies where black holes with the mass of 1,000 million stars are actively sucking in material.

Collecting radiation

Orbiting telescopes that detect ultraviolet in orbit produce false colour images of very hot stars – these generate a great deal of ultraviolet radiation. They have a mirror covered with a reflective coating that focuses light. The image is detected by an array of cells sensitive to ultraviolet radiation.

The ultraviolet region of the electromagnetic spectrum (91–320 nanometres or $91-320 \times 10^{-9}$ metres) is particularly interesting to astronomers. Radiation at these wavelengths can give information about cold dust clouds as well as exotic objects such as quasars – the brilliant centres of young galaxies far off in the universe. The hot stars are much brighter at ultraviolet wavelengths. A star with a surface temperature of 40,000°C is approximately one hundred times brighter in ultraviolet than in visible light. (Our Sun has a surface temperature of only about 6,000°C.)

Radio telescopes on the ground take advantage of the fact that the



atmosphere is particularly 'transparent' to microwave radiation and medium wave wavelengths section. Radio 'scopes collect radiation in a dish and beam it to a detector. The signals are relayed to a computer and interpreted into images that show the shape of an object and the strength of the emissions of the radio source in the sky.

To make radio astronomy telescopes as powerful as possible, telescopes far apart are linked up to form what are known as Very Large Array (VLA) telescopes.

Q AGE OF THE SUN

Q COSMIC SOOT

Q PROTO-STARS

STAR BIRTH



Four new stars – known as the Trapezium Cluster – are clearly visible in the swirling gas and dust of the Orion nebula.

STARS ARE BORN IN VAST clouds of dust and gas, and take many years to evolve into the brilliant objects that illuminate our night skies

Stars are immense balls of hydrogen and helium, which shine by the same nuclear reactions that power hydrogen bombs. The Sun around which the Earth and other planets revolve is a typical middle-aged star.

At its core hydrogen is being converted to helium at the rate of 4 million tonnes per second,

which releases vast amounts of energy. Though this sounds an enormous figure, astronomers know that there is enough of this 'nuclear fuel' to power the Sun for another five billion years.

It has been known for some time that stars are formed in nebulae – clouds of dust and gas – some of which can be seen in the night sky. To the naked eye, the Great Nebula in Orion appears as part of the mighty hunter's sword. But many nebulae are cold and dark and cannot be seen with even the most

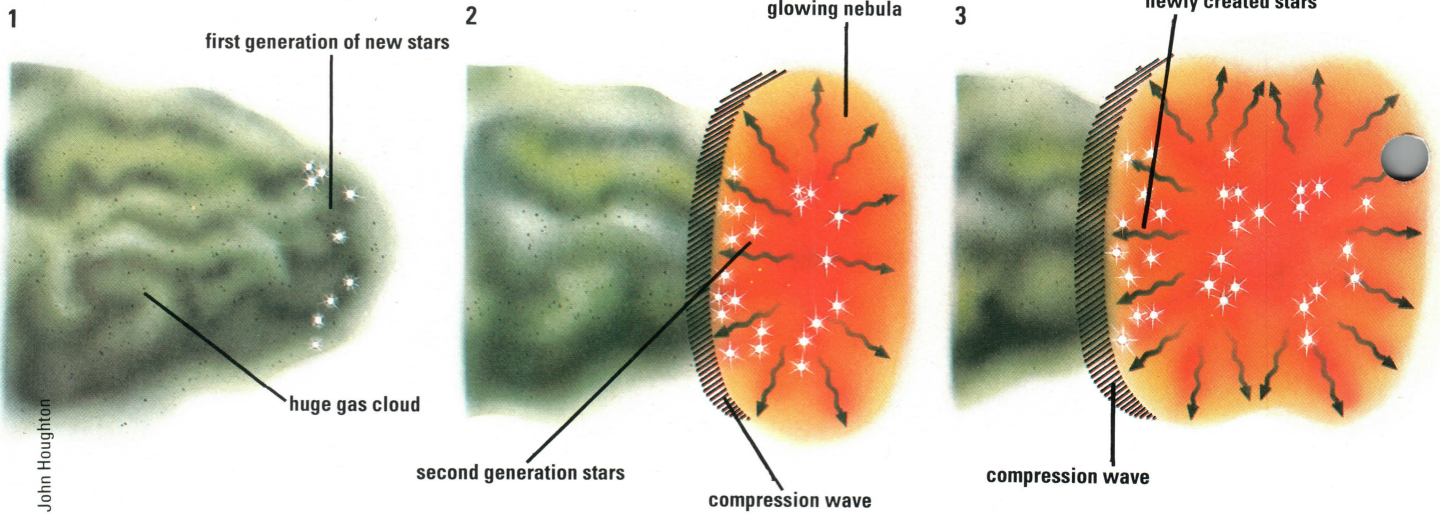
powerful optical telescopes.

In 1983 a satellite called IRAS – the Infra-red Astronomical Satellite – was launched. It revealed that many nebulae extend much further than they appear to in ordinary light, the outer regions of dust and gas glowing at the longer infra-red wavelengths.

The dust is a vital ingredient in starbirth, even though it only accounts for 0.1 per cent of the material between the stars in our Galaxy. Some of it is made of ice,



HOW STARS ARE BORN



One theory of star creation. A first generation of stars forms near the surface of a giant cloud of gas, 1. Their heat compresses it, 2, creating more new stars, 3.

It contains ice crystals, silicon and even organic compounds, such as formaldehyde. But most of it is carbon in the form of small dust grains – cosmic soot. Other molecules have been revealed by radio telescopes that can, literally, 'tune into' their atomic vibrations.

Stars go nuclear

The dust and gas gradually begins to come together under the influence of its own gravity, helped by other processes that compress the gas – such as collision with the expanding shells of material thrown off by dying stars. Massive stars may undergo a tremendous supernova explosion, in which most of their material is thrown off into space, adding greatly to the dust and gas already in the vicinity, and further compressing the gas. Eventually, in regions where the density of mate-

Dr Fred Espenak/SPL

Infra-red and radio telescopes have shown that interstellar clouds contain organic molecules, including long chains of carbon atoms, the molecular 'backbone' of life. Astronomers Sir Fred Hayle and Chandra Wickramasinghe believe that comets pick up this material and incubate it in the gas and dust

at the comets heart. Under such conditions, viruses could evolve like those that cause colds, flu, legionnaire's disease and even AIDS. New strains of these diseases, they say, rain down on the Earth each time a comet goes by. Other astronomers and micro-biologists are not convinced by this theory.

rial is sufficiently great, the dust and gas condenses into a vast swirling concentration – a proto-star.

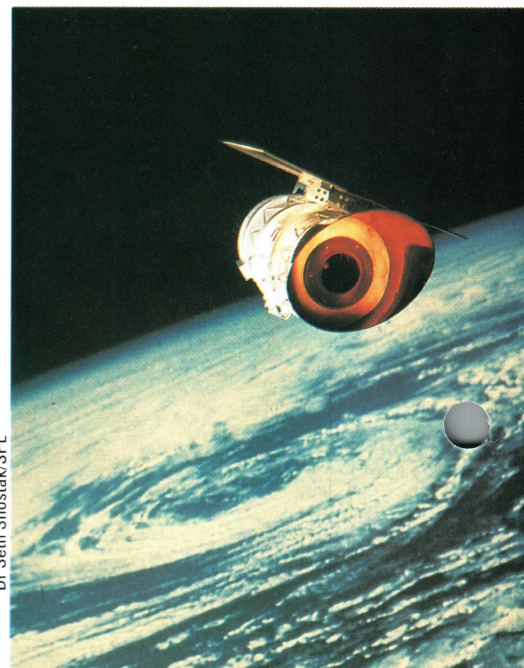
The proto-star continues to contract (shrink), and as it does so the temperature at its centre increases. The more massive the proto-star, the higher its central temperature. Some proto-stars are so small that they will never become hot enough for nuclear reactions to begin. But a proto-star of sufficient mass will, after many tens of thousands of years, 'go nuclear' (start to shine), when its central (core) temperature reaches ten million degrees Celsius. This is the moment of starbirth.

The new-born star emits large quantities of radiation, which can disrupt the formation of other stars in the vicinity. However, after its violent birth, the star settles down to a period of relative stability. Any remaining dust and gas in close proximity to the star may clump together to form planets, comets and meteoroids, such as in our own Solar System.

SPACE VIRUSES



The infra-red astronomical satellite (IRAS) revolutionized our view of starbirth. It circles the earth 14 times a day.



Dr Seth Shostak/SPL

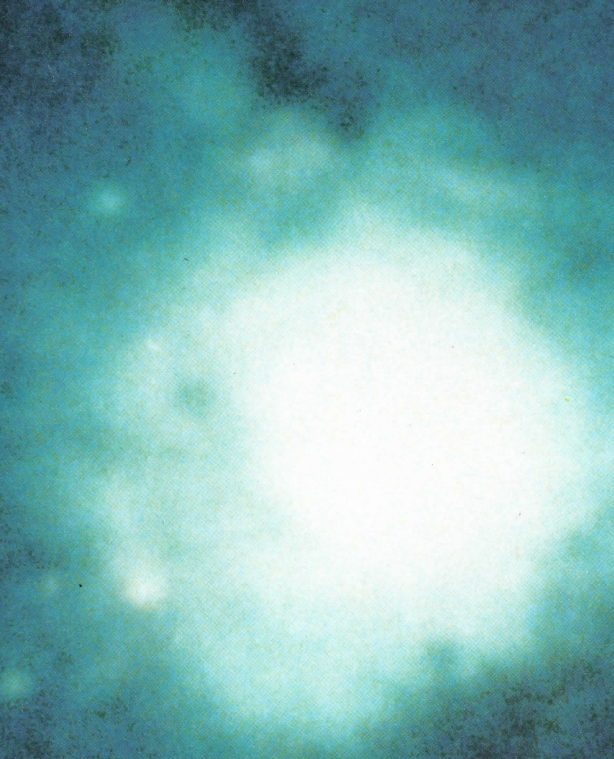
Just amazing!

POWER CRAZY

CONVERTING 1 GM OF HYDROGEN TO HELIUM BY A NUCLEAR REACTION RELEASES ENERGY EQUIVALENT TO A YEAR'S PRODUCTION FROM 5 BILLION LARGE HYDRO-ELECTRIC STATIONS.



Paul Raymond



In the Big Bang, the Universe was created – but this was not an event that happened at a particular time and at a particular place. Time and space were created too.

WHEN TIME BEGAN

Q THE BIG BANG

Q BLACK HOLES

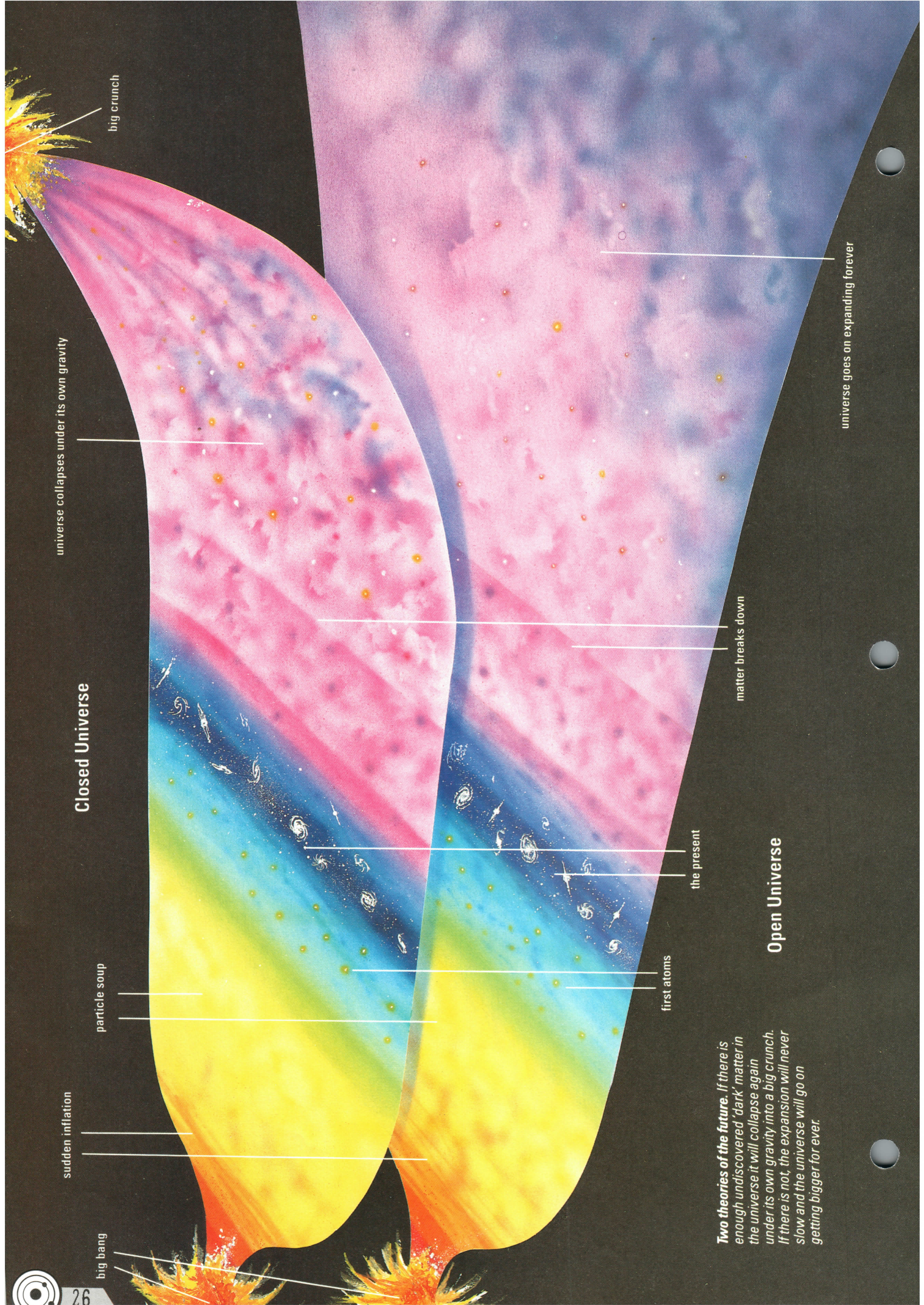
Q THE END OF TIME

ONCE UPON A TIME, AROUND 15 billion years ago, time and space were created. Before that, nothing happened – nothing could happen because there was no time for it to happen in. Nor was there anywhere for it to happen.

At the same instant as time and space were created, so was the stuff that turned into the matter and energy we find in the Universe today. The event that created time, space, energy and matter is known as the Big Bang.

We cannot actually explain what happened in the Big Bang – the normal laws of science break down when time is not passing. But the fact that a Big Bang did occur is beyond any doubt.

Astronomers have observed that galaxies are hurtling away from us –



big crunch

universe collapses under its own gravity

Closed Universe

particle soup

sudden inflation

big bang

matter breaks down

the present

first atoms

universe goes on expanding forever

Open Universe

Two theories of the future. If there is enough undiscovered 'dark' matter in the universe it will collapse again under its own gravity into a big crunch. If there is not, the expansion will never slow and the universe will go on getting bigger for ever.

Atom smashers like this giant synchrotron at the nuclear research centre in Geneva use very high energies to recreate the conditions that existed soon after the Big Bang. Inside, massive magnets accelerate tiny particles round a huge 'racetrack' (below), then smash them into each other.

PHOTO CERN

and from each other — at great speeds. In fact, they are not moving *through* space. It is the space between them that is expanding. Imagine the galaxies as dots on a balloon. As you blow up the balloon, the dots get farther apart.

From the fact that space is expanding, it has been deduced that everything was once together in one 'place' — the 'place' where the Big Bang occurred. However, what was once a single point is now a huge sphere all around us.

Because light takes time to reach us, looking out into space is like looking back in time. For example, the light from Barnard's Star takes nearly six years to reach Earth, so when we look at Barnard's Star we see it as it looked six years ago. It could have blown up in the meantime and we would not know yet — not till six years after the explosion. Similarly, someone living on a planet orbiting Barnard's Star would, if they could observe the Earth see what was happening six years ago.

If you look past Barnard's Star, out towards the edge of the Uni-

PHOTO CERN

Scientists look for quarks among the resulting cloud chamber tracks. These tiny particles existed after the Big Bang.

verse with a radio telescope, you can 'see' back billions of years to almost the time of Big Bang itself.

The revolutionary physicist Albert Einstein showed in his General Theory of Relativity that time slows in the presence of gravity. So back at the beginning of time, when all matter was so tightly compacted that its density — and its gravity — was huge, time must have passed much more slowly than it does now. So we can only begin to understand what happened in the Big Bang a short while after the beginning of time.

When the Universe was just 10^{-43} seconds old — that is, one ten million, trillion, trillion, trillionth of a second after the Big Bang — all matter of space, everything, was squeezed down to less than the size of the nucleus of a hydrogen atom (which is around a trillionth of centimetre across) and the temperature was one billion, billion, billion degrees.

Inflation

A little later, around 10^{-34} seconds, or one ten billion, trillion, trillionth of a second after the Big Bang, a major event in the history of the Universe

Stars are formed when huge interstellar clouds of dust and gas collapse under the influence of their own gravity.

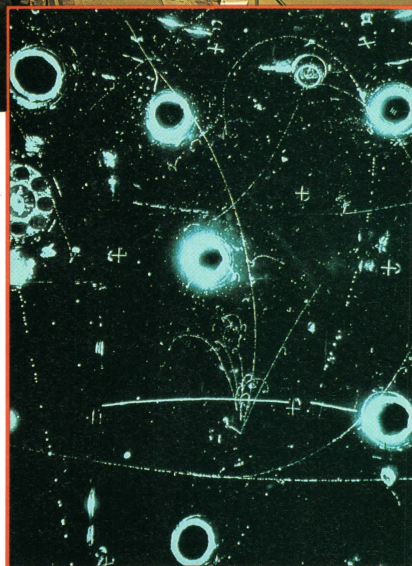
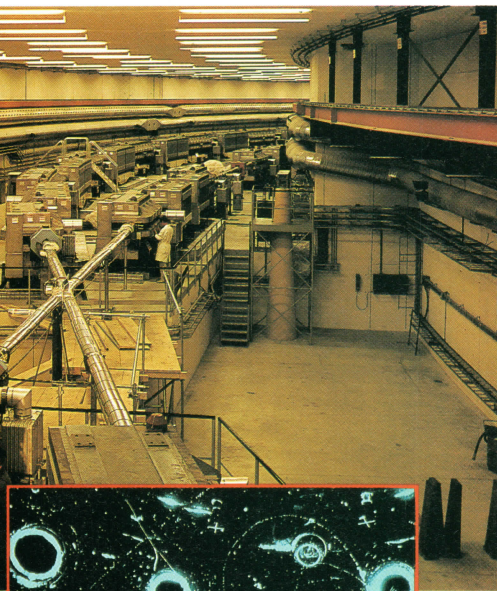


PHOTO CERN

occurred — it suddenly inflated to around 10 cm across. At this point, a flood of particles were created which would eventually form atoms. (These were the basic building blocks of the matter we know today). There were also neutrinos, which are ghostlike particles that can pass through the Earth as if it did not exist.

Atom-building began when the Universe was around a second old and had cooled to a mere 10 billion degrees. Over the next three minutes or so, the nuclei of the lightest elements — hydrogen, helium and lithium — were created.

For the next 300,000 years, as the Universe continued to expand, light and other electro-magnetic radiation dominated. But when the temperature dropped to around 10,000 degrees and the matter thinned out, electrons were captured by nuclei atoms. With no free electrons to

Spectrum Colour Library



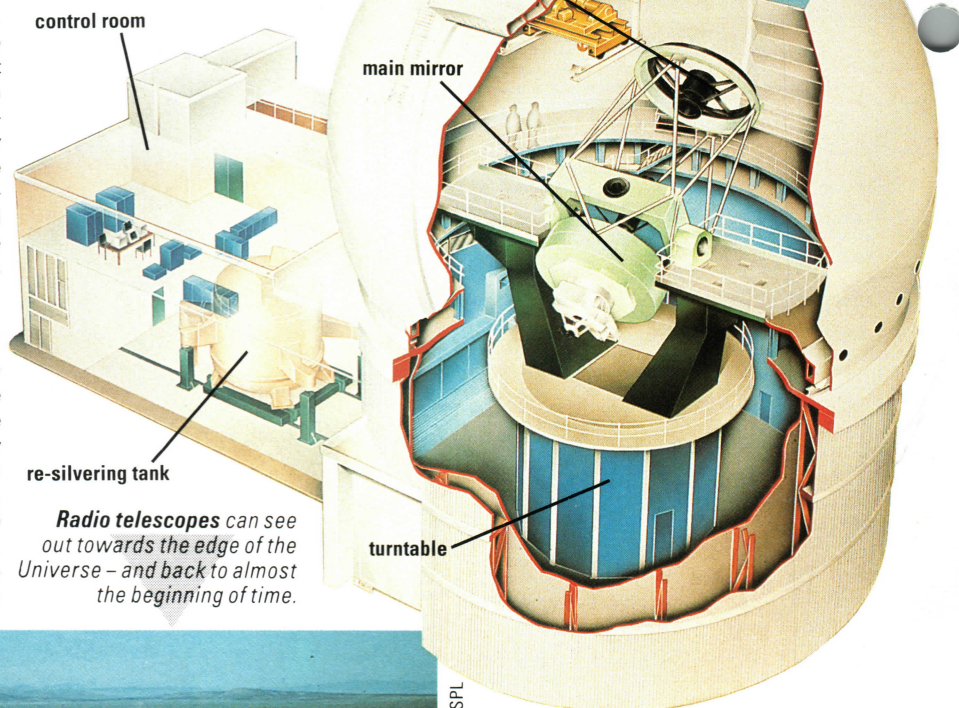
interact with the radiation, the Universe suddenly became transparent. But as it was only a huge, expanding cloud of thin, hot gas there was not much to see.

As the Universe continued to expand it cooled and grew dark. Gradually the huge cloud began to break up. Bits of it began to contract under the influence of their own gravity. 'Small' clouds began to condense into what would one day become stars and galaxies. As these clouds collapsed further, the pressure built up at their centres increased and set off nuclear reactions. These gave off light and the first stars began to illuminate the heavens.

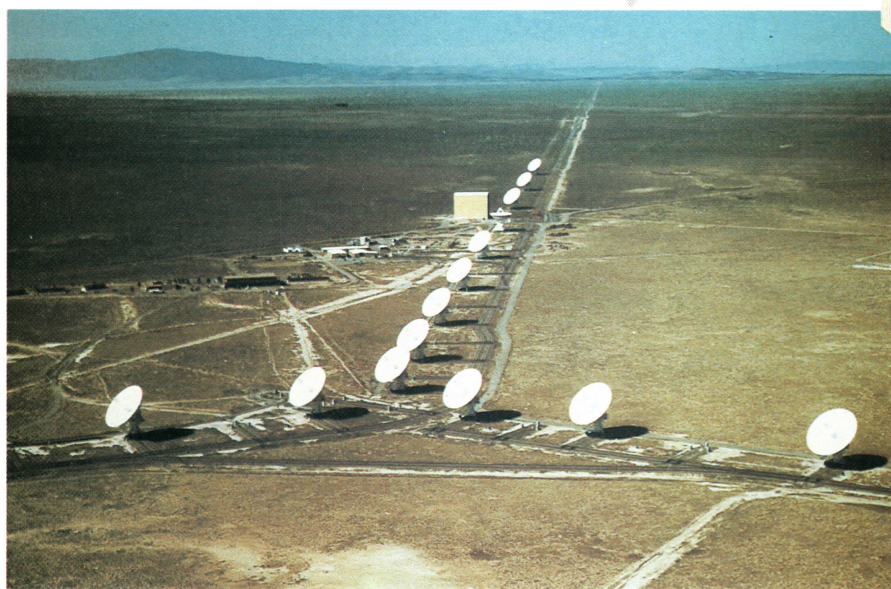
Black holes

Stars are still being born today. The more massive ones – 10 or more times the mass of our Sun – age rapidly and explode after only a few million years. Some leave behind a tiny, dense remnant, a neutron star, perhaps 10 km across but of 10 trillion times as dense as lead. Others leave a remnant that is so dense its massive gravity prevents

Large reflecting telescopes like the William Herschel Telescope on the Canary Islands observe the galaxies speeding away from each other.



Radio telescopes can see out towards the edge of the Universe – and back to almost the beginning of time.



NRAO/AUI/Science Photo Library Royal Greenwich Observatory/SPL

planets and the interstellar gas will have vanished and black holes will be almost the only matter remaining.

These black holes will themselves 'evaporate', giving out immense quantities of energy in the process. The most massive black holes – those the size of an entire galaxy – will take a million trillion trillion trillion trillion trillion years to disappear. Then the Universe will be a featureless sea of tiny particles and electromagnetic radiation all speeding away from each other at immense speeds. Time will slow to a halt.

even light escaping. This is a black hole.

Our Sun will live for about 10 billion years. But towards the end of its lifetime it will expand to engulf the planet Mercury, then contract, cool and slowly fade to darkness.

Scientists are not sure whether the Universe will continue expanding for ever. The matter we can see in galaxies is not enough to halt the expansion by gravity alone. But it is thought that there may be a lot of 'dark' matter, so far undiscovered – the only things we can really see in the heavens are stars that give off light. The gravitational pull of this dark matter could halt the expansion. If it did, the Universe would collapse back to a single point in a 'Big Crunch'. In the Big Crunch, time would end.

If there is no 'dark' matter and the

Universe does not collapse, it will go on expanding forever, spreading its contents over ever increasing distances. A hundred billion years from now, the cluster of galaxies will have broken up, though stars will still be forming in individual galaxies. It will not be until a hundred trillion years from now that the last stars will fade into darkness.

After 10 million trillion years, the galaxies will have disappeared as most of their long-dark stars will have escaped from them. Some 10 per cent of stars will have fallen into the black holes.

Death of matter

Matter itself will begin to die and, over 10 million trillion trillion years, will break down into smaller particles and electromagnetic radiation. By then the dead hulks of stars,

Just amazing!

LIGHTNING SPEED

LIGHT TRAVELS AT 300,000 KM A SECOND – OVER ONE BILLION KM AN HOUR. IN ONE SECOND, A LIGHT BEAM COULD TRAVEL ROUND THE EARTH SEVEN TIMES.



Paul Raymonde



A moon-farm would need a protective dome. Scientists have already created a prototype, Biosphere 2 in Arizona, USA, where fish and other animals were farmed and where crops were grown.

ASTRO AGRICULTURE

- SPACE FARMS
- MOON COLONIES
- BIOSPHERES

SCIENCE FICTION IS FULL OF 'cities in space' – giant space stations supporting people, plants and animals. Are such self-supporting cities on other planets feasible? Or what about a wheel-shaped space station growing crops and sending them back to Earth?

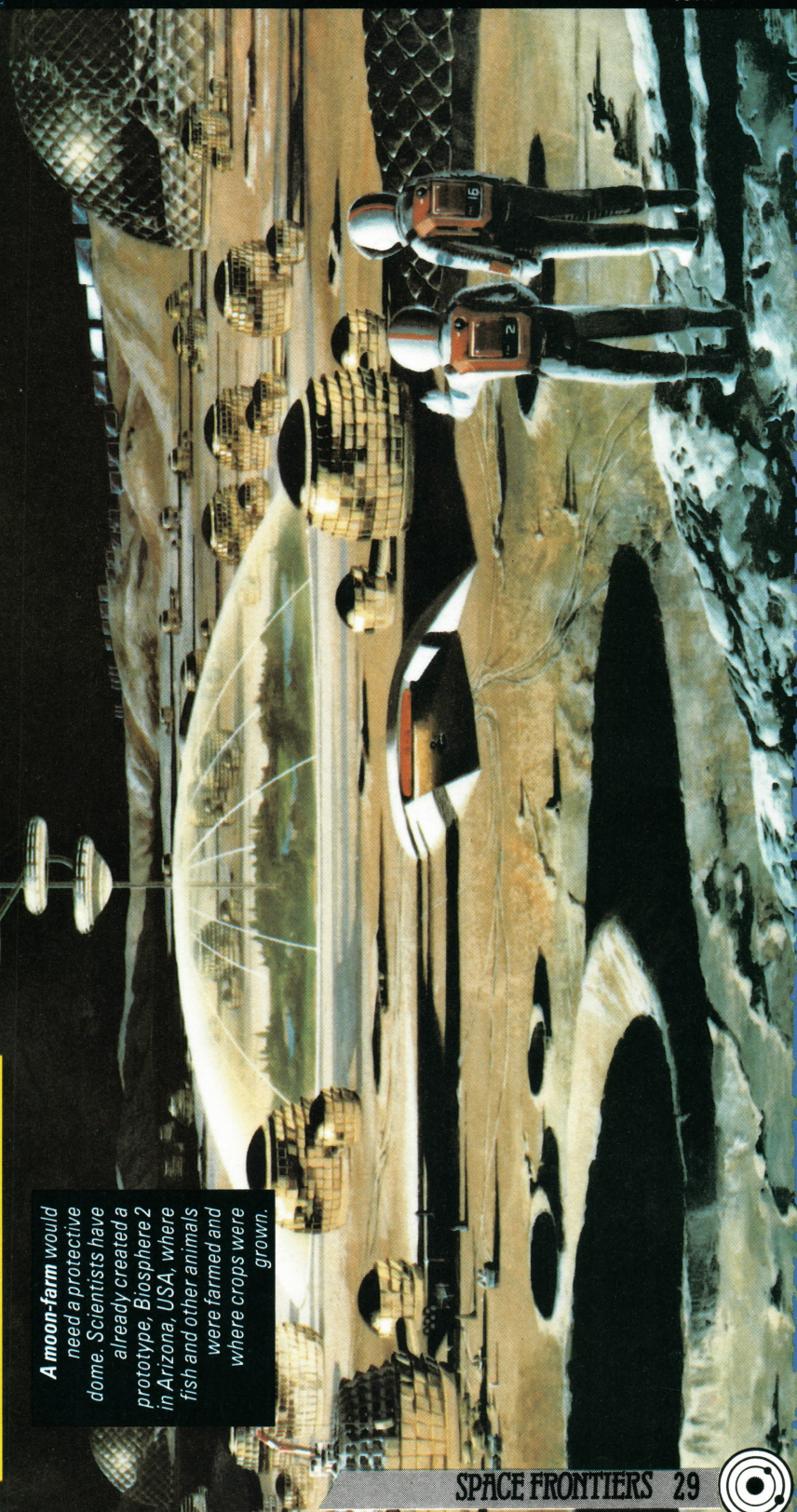
In theory, space has plenty of raw materials, and abundant energy from the Sun's light and other radiations. But could we use space-farms to grow crops and raise livestock? Once set up, a space-farm would need to become self-supporting – just like 'spaceship Earth'. The main difficulties could be starting it up and getting the balance right.

Solar energy

The idea of the space-farm has many attractions. We could grow only those plants and animals we wanted. Weeds, parasites, disease pests and wild animals that 'cash in' on the farmer's produce could all be left behind.

In space, the Sun shines brightly and continuously, giving out large amounts of energy which could be used by plants directly. Vast arrays of solar cells could turn sunlight into electricity, to power all the machinery on the farm.

But some crops need day and night, in order to go through their life cycles of germinating, growing, flowering and fruiting. Many animals, too, respond to the lengthening days of spring by coming into sexual condition ready to breed. These processes are controlled by daylight length. So too much sunlight might



be harmful. To avoid this, computer-controlled mirrors could shine the light on certain areas at certain times, mimicking the days and nights of Earth. Or blinds might be drawn across the overhead dome of a Moon-farm.

Gravitational pull

Many plants become confused if grown without gravity. Their roots normally grow down and their shoots head upwards (this is called geotropism). Without gravity, the roots might head out of the soil while their leaves try to burrow underground. So the space-farm would need a gravitational field.

The Moon's gravity, at one-sixth of the Earth's, might do. But a floating space station would have to spin slowly to produce gravity – and make the farmers feel more at

Moon rock is very similar in make-up to rocks on Earth. The oxides in it can be turned into oxygen for breathing and water, while the silicon can be used to make glass and concrete. This would enable scientists (using solar power as a cheap form of energy) to cut the costs of building Moonfarms.



breathe, so they could refresh the air, just as they do on Earth.

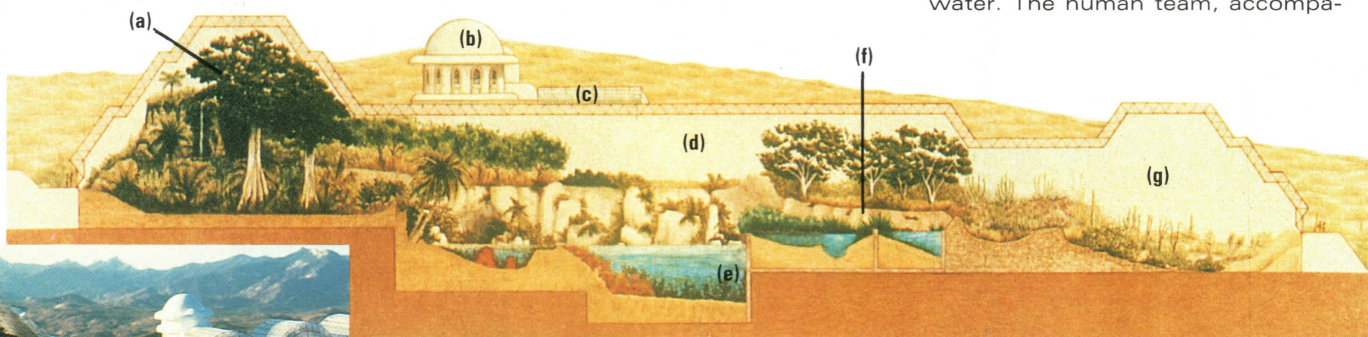
It would cost a fortune to build space farms on Earth and then launch them. But the silicon in Moon rock can be used to make glass and concrete on the Moon,

tares (3.5 acres).

Four men and four women entered the building on September 26, 1991 and re-emerged exactly two years later. Biosphere 2 was designed to be completely sealed off from the outside world, so that it produced and recycled all its air and water. The human team, accompa-

NASA/SPL

Space Biospheres Ventures



Biosphere 2 contained seven 'biomes' – or types of environment. These are (a) tropical rainforest, (b) urban, where the residents will live, (c) an area for intensive agriculture, (d) savannah, (e) an 'ocean' ten metres deep, (f) marshland, and (g) desert.

nied by about 3,800 species of carefully selected plants and animals, grew their own food and recycled their own wastes. The only energy they received came, as in space, from the Sun.

Although a few emergency departures from the original objectives took place, such as the addition of oxygen when carbon dioxide levels twice rose dangerously high, Biosphere 2 still represented a beginning for the development of a space farm.

home!

Moon rocks are similar to the rocks on Earth. Both contain the same proportions of oxygen (60 per cent), silicon (17 per cent) and aluminium (8 per cent). So the Moon has one of life's great needs – oxygen – but not in the gaseous form we breathe. It is combined with other chemicals such as silicon (to make 'Moon-sand') and aluminium.

Moon water

Yet within two years of the first Apollo landing in 1969, scientists had shown that it was possible to produce both water and oxygen from lunar dust. Once enough water had been created, it could be recycled endlessly – just as on Earth.

The process of photosynthesis means that plants could convert carbon dioxide into oxygen for us to

saving up to 97 per cent of the launch costs.

Temperatures on the Moon vary from 120°C during the day to -170°C at night. A giant dome of plastic or glass would be vital to any space-farm. It would keep in the 'atmosphere' of gases and protect the inhabitants from cosmic and other harmful radiation, and from showers of tiny meteorites.

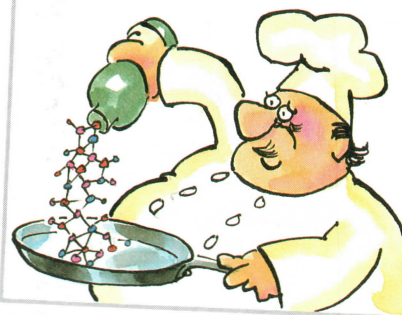
Heat-absorbing fluid could be circulated through tubes in the dome's walls, to absorb the Sun's heat. This heat could be used to generate electricity or to warm underground rocks, as a sort of 'heat reservoir'. Then in the ultra-freezing night the heat would be released to keep the farm warm.

A giant greenhouse-like building was built in the Arizona desert as a model for a future space-farm. Called Biosphere 2 (Biosphere 1 being the Earth itself), it covered 1.4 hec-

Just amazing!

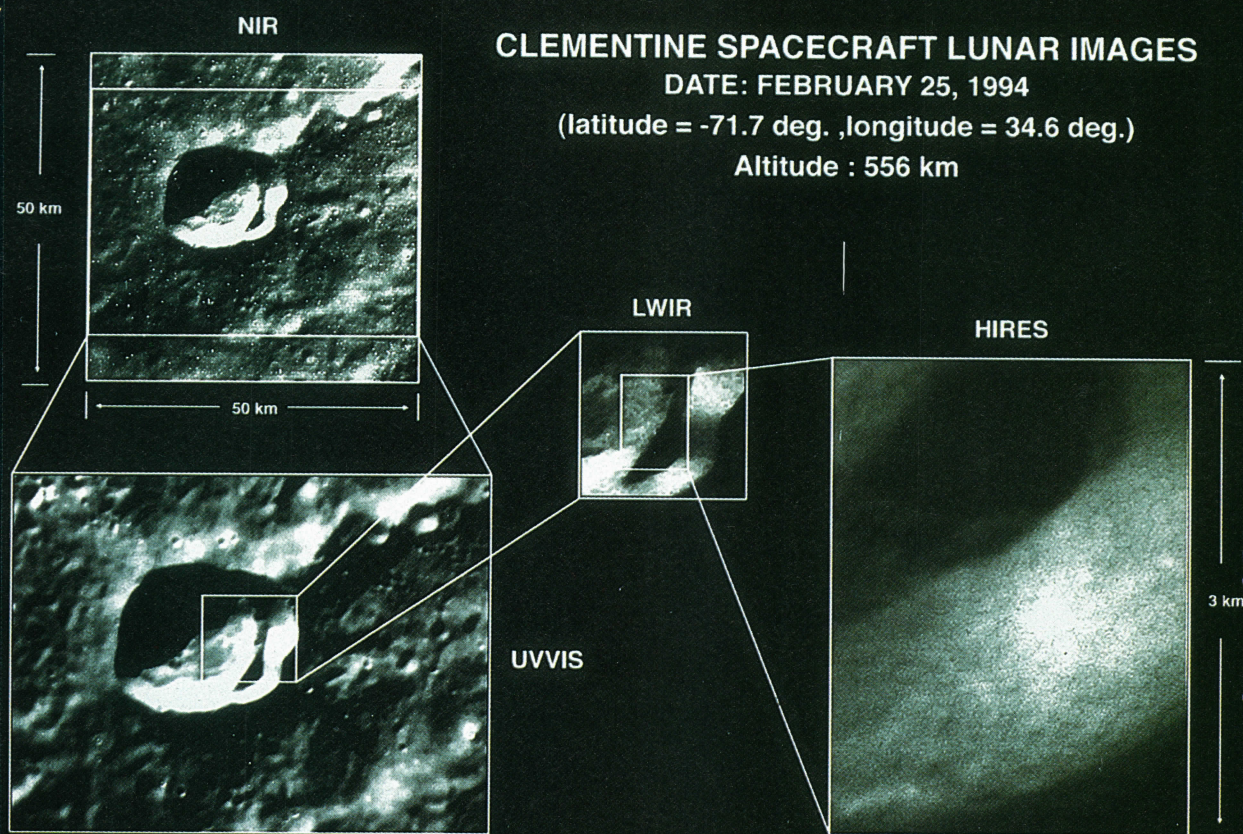
FAT-FREE FAT

ONE AMERICAN COMPANY HAS DEVELOPED A FAT WHICH HAS NO CALORIES. IT IS MADE UP OF GIANT MOLECULES, WHICH CANNOT BE BROKEN DOWN AND PASS THROUGH THE BODY UNDIGESTED.



Paul Raymond

GLOBAL DEFENCE SYSTEM



A GLOBAL DEFENCE SYSTEM TO protect the Earth from being hit by a large asteroid has been proposed by scientists in the United States.

Such an impact, by an asteroid perhaps 10 kilometres across, is thought to have been responsible for the extinction of the dinosaurs – and, indeed, of more than half the species on Earth – at the end of the Cretaceous period, around 65 million years ago.

The risk of a similar catastrophic impact today, although slight, is by no means non-existent. Astronomers have estimated that there may be as many as 4000 near-Earth asteroids (NEAs – ones that regularly cross the Earth's orbit) more than 1 kilometre across, any one of which could cause widespread destruction. And in 1989 just such an object passed within 700,000 kilometres of the Earth – a hair's breadth on the astronomical scale of things! More recently, in 1908, a comet fragment approximately 100 metres across

struck Tunguska, in central Siberia. It exploded 8 kilometres above the ground with the force of a 12 megaton nuclear bomb. Everything within 30 kilometres was flattened. Fortunately, this is a remote area and no humans were killed.

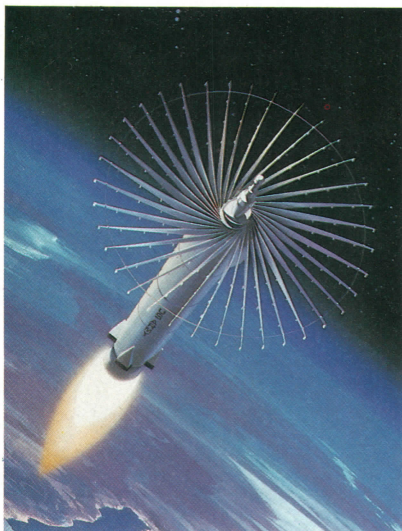
The US scientists have taken a two-tier approach. First, telescopes such as the 0.9 metre Spacewatch reflector on Kitt Peak, in Arizona, are scanning the sky for new NEAs, of which less than 200 are known, so that their orbits around the Sun can be calculated and the possibility of a collision assessed. In March 1994 the Kitt Peak telescope tracked a previously unknown 10 kilometre asteroid which skimmed past the Earth at a mere 160,000 kilometres. But it is of little use being able to predict a collision if we are able to do precious little about it.

The second tier of the US scientist's approach does intend to do something about it, namely to deflect the course of a threatening

Photos of the Moon's surface showing the massive craters created by asteroid impacts. It is hoped that new technology could avoid such catastrophic impacts on Earth.

asteroid or even blast it out of the sky using 'Star Wars' technology. Such a capability does not yet exist, but research into space weapons has been ongoing since 1984, when politicians first approved funding for the so called Strategic Defence Initiative (SDI). SDI, or 'Star Wars' as it became popularly known, was intended to provide a shield for the United States from potential Soviet nuclear attack by intercepting incoming intercontinental ballistic missiles using laser 'killer' satellites, 'kinetic energy weapons' (in which a collision would destroy both the weapon and the missile) and large orbiting mirrors that would reflect destructive laser beams fired from the ground on to their targets.

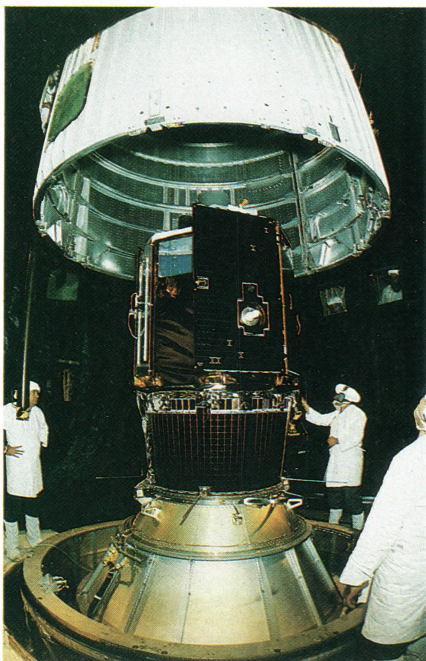




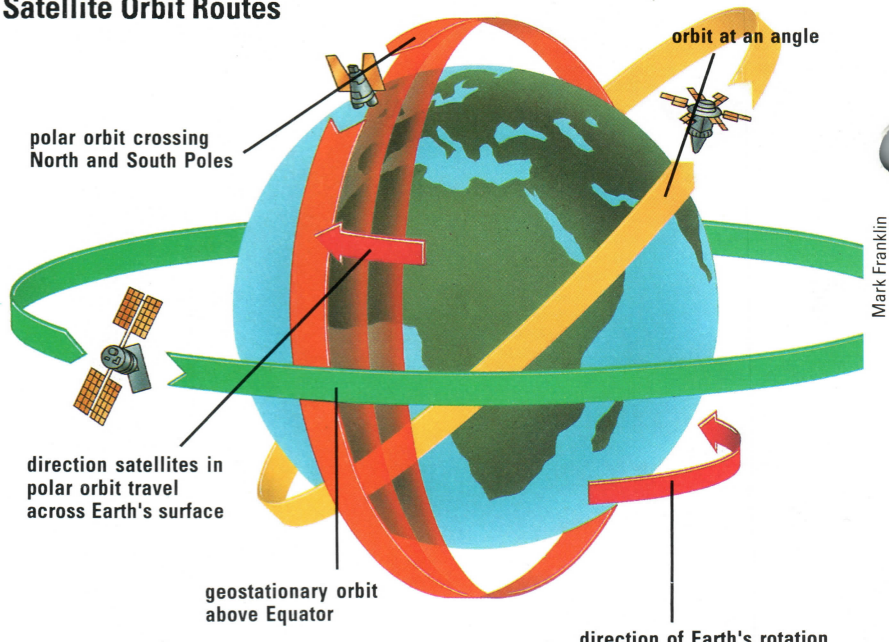
A 'Brilliant Pebble' missile destroys a hostile missile by crashing into it. To increase the chances of a collision, the fan-like structure opens out just before impact.

However, problems were encountered in trying to turn theoretical concepts into practical devices, and this coupled with a perceived lessening of the Soviet threat led politicians to reduce the SDI budget. SDI became GPALS (Global Protections Against Limited Strikes), in which the goal was to use 'kinetic energy weapons' launched from the ground, air or possibly space to destroy a few missiles fired at the United States, its overseas forces or one of its allies accidentally, or deliberately by terrorists. With the threat

The Clementine probe before its launch. The probe carries newly developed miniature sensors and lightweight components.



Satellite Orbit Routes



Mark Franklin

Satellites in geostationary orbit above the Equator take 24 hours to circle once and move east with the Earth, so they always stay above the same point on Earth. Those orbiting over the Poles, as the Earth below slowly turns, travel over most of the Earth's surface. *Satellites orbit at an angle when launch sites, or the area to be covered, are too far from the Equator for geostationary orbit.*

of further cutbacks in funding, 'Star Wars' scientists were eager to justify their research, and what better than to propose a global defence system to protect the Earth from possible asteroid impact?

In January 1994 *Clementine*, a satellite designed to test new lightweight components and sensors for tracking missiles in the Earth's atmosphere, was launched towards the Moon. It was to spend two months mapping the lunar surface,

before proceeding to the 4x1.5 kilometre NEA Geographus, which it was to fly past at a distance of only 100 kilometres at the end of August.

Another satellite, *Near Earth Asteroid Rendezvous* (NEAR), is scheduled to be launched in February 1996. This is intended to encounter the 24 kilometre NEA Eros in December 1998 and to orbit it for a year, passing within 30 kilometres of its surface.

While the setting up of a global defence system probably lies some years away, the possibility of such a system and the interest aroused in asteroid impact has given the 'Star Wars' scientists another lease of life and has revitalized the astronomical study of NEAs.

BUGS IN SPACE

When planning a defence system, it must be a top priority to find out as much as possible about the enemy's defence and attack systems. ELINT (ELectronic INTelligence) satellites listen in to radio communications. For military purposes, the ability to eavesdrop on an opponent's radio links is very important because it gives a clear picture of what he intends to do in a particular situation. COMINT (COMmunications INTelligence) satellites pick up transmissions from radar stations. By listening to and recording radar transmissions, military planners can work out the location of enemy weapon systems and glean information on how they work.



Paul Raymond

- Q DIY REPAIRS
- Q SHUTTLE RECOVERY
- Q LAUNCH DISASTER



The rescue ball is designed to transfer Shuttle crew members from a crippled ship (inset).

SPACE RESCUE

HEADING FOR THE MOON, thousands of kilometres from Earth in a disabled ship, rescue is out of the question. How can the stranded astronauts be saved?

'OK, Houston, we've had a problem.' With these chilling words, Apollo 13 command module pilot Jack Swigert told NASA ground crew at mission control that his spacecraft was in deep trouble.

It was 9.09 p.m. on Monday, 13 April 1970. Apollo 13, with its crew of commander Jim Lovell, lunar module pilot Fred Haise, and Swigert, was 330,000 kilometres from Earth and bound for a third

manned landing on the Moon. Suddenly, the ship trembled and the astronauts heard a loud bang. Though no-one knew it at the time, an oxygen tank in the service module had exploded, ripping off a side panel completely and severing a vital fuel line to the command module in which the astronauts lay.

The lunar module

Almost immediately, the Moon landing was cancelled. All efforts were focused instead on simply trying to save the astronauts' lives. With its main fuel supply cut off, the command module would quickly

run out of power. The only option left was for the crew to crawl into the lunar module, called Aquarius, and use it as a kind of lifeboat in which to return to Earth. Unfortunately, Aquarius was only designed to support two men for up to two days. Now it would have to keep alive a crew of three for the four-day journey home.

Conserving water

Air, water, and electricity were rationed to the bare minimum. As a result, the cabin temperature gradually fell to just a few degrees above freezing. Resting in shifts,



the astronauts used the command module as their 'upstairs bedroom', although it was so chilly they could hardly sleep. To conserve water, each man was allowed only half a litre a day – one fifth the normal amount.

One of the most tense moments

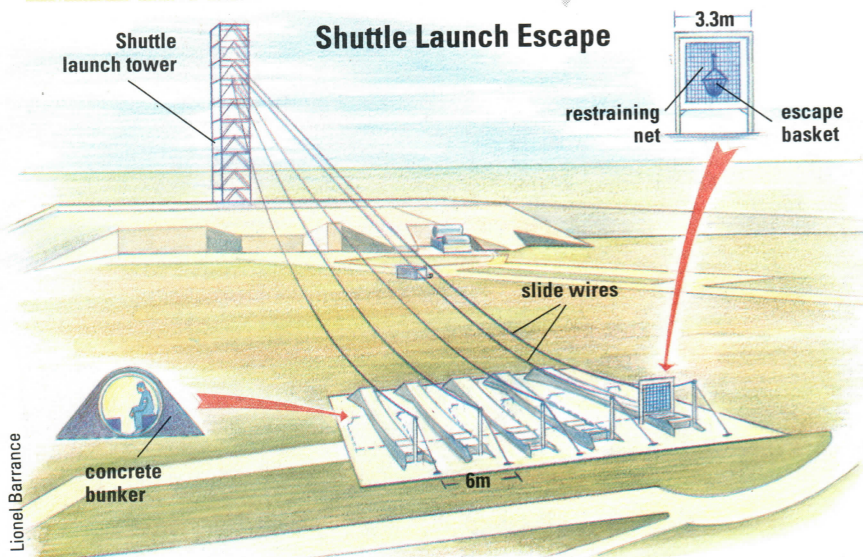
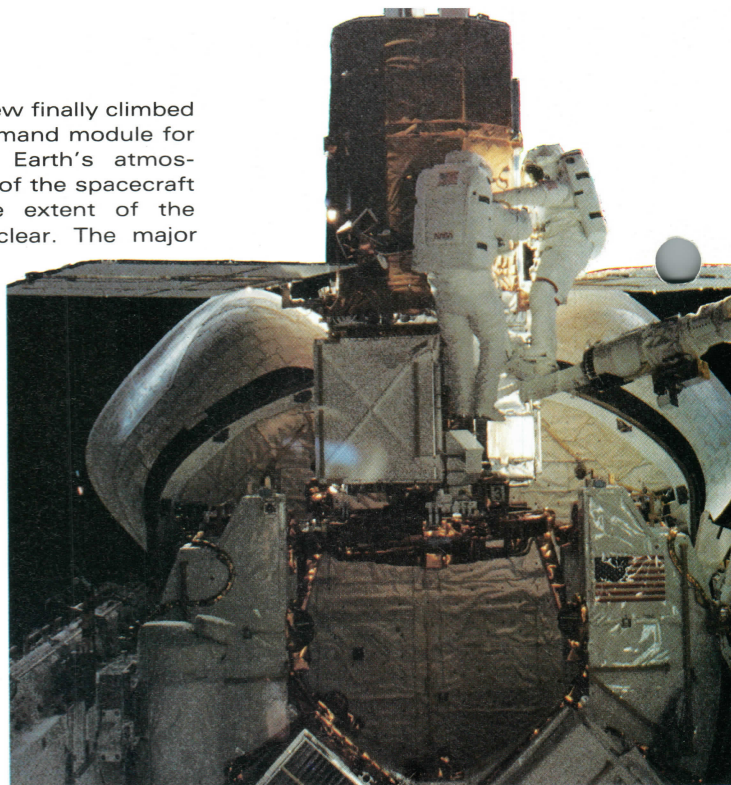
LAUNCHPAD DISASTER

On 28 January 1986, the Shuttle orbiter Challenger was launched for the tenth time. But 73 seconds into the flight the accelerating Shuttle suddenly exploded and was blown apart. The crew of seven – astronauts Dick Scobee, Mike Smith, Judy Resnik, Ron McNair, Ellison Onizuka, Greg Jarvis, and teacher Christa McAuliffe – all perished in the worst space disaster ever. The cause of the explosion was a leaking joint in one of the booster rockets. As a result of the disaster, many modifications were made to the Shuttle, and flights did not resume until September 1988.

came when the crew finally climbed back into the command module for re-entry into the Earth's atmosphere. As the rest of the spacecraft was cast-off, the extent of the damage became clear. The major

Astronauts George Nelson and James van Hoften use the Shuttle's Remote Manipulator System to help them repair the rescued Solar Maximum Mission Satellite.

In an emergency, Shuttle crew members can escape by sliding down cables in a metal basket to reinforced ground bunkers 400 metres from the base of the tower.



dioxide they were breathing out, because the lunar module's air system was overloaded. In desperation, they taped hoses from a Moon-suit to a plastic bag which they then fitted tightly around the command module's air filter to create an atmospheric 'scrubber'.

NASA

Space station

In June 1985, two Russian cosmonauts blasted off on a mission to revive the orbiting Salyut-7 Space station that had frozen up because of an instrument failure. The two men, who were specialists in Space repair work, had to dock their ship manually since the lack of power aboard the station ruled out an automatic link-up. They then set about recharging Salyut-7's dead batteries, warming up the Space station, and replacing electronic equipment that had been damaged.



concern now was whether the explosion had also damaged the heat shield at the back of the command module. Luckily, it had not. On 17 April, Apollo 13 splashed down safely in the Pacific Ocean.

The incredible adventure of Apollo 13 and the later tragedy of the Challenger disaster underline how hazardous space flight can be.

However, in the Shuttle era, orbiting astronauts stand a better chance of being rescued in an emergency. This is because there is usually a Shuttle on the launch pad most of the time being prepared for lift-off. And it could be switched to a rescue mission with the minimum of delay.

Suffocating

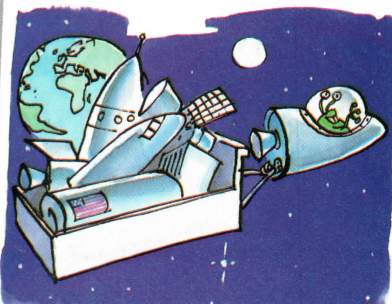
When equipment fails in Space it is up to the crew, with advice from mission control, to try to repair it or to rig up some makeshift apparatus in its place. The Apollo 13 astronauts, for instance, faced the prospect of suffocating on the carbon

The docking procedure used during the Lunar-landing missions would be the mainstay of any rescue of a stranded spacecraft.

Just amazing!

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